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ABSTRACT

This individualized learning module on voltage is one in a series of modules for a course in basic electricity and electronics. The course is one of a number of military-developed curriculum packages selected for adaptation to vocational instructional and curriculum development in a civilian setting. Six lessons are included in the module: (1) Electromotive Force for Chemical Action, (2) Magnetism, (3) Electromagnetic Induction, (4) Alternating Current Voltage, (5) The Uses of Direct Current and Alternating Current, and (6) Measuring Voltage. Each lesson follows a typical format including a lesson overview, a list of study resources, the lesson content, a programmed instruction section, and a lesson summary. (Progress checks are provided for each lesson in a separate document, CE 026 562.) (LRA)

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ED190879

NAVEDTRA 34258-2

CHIEF OF NAVAL EDUCATION AND TRAINING

MARCH 1977

Military Curricula for Vocational & Technical Education

BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM.

MODULE TWO. VOLTAGE.

STUDY BOOKLET.

CE 026 564

U S DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses is to make curriculum materials developed by the military accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

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The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

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The Ohio State University
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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

OVERVIEW

MODULE TWO

VOLTAGE

In this module of the Basic Electricity and Electronics Course, you will study and learn what voltage is, how it is generated, what AC and DC voltages are and why both kinds are needed, and how to measure voltages.

This module is divided into six lessons to help you learn more easily. These are:

Lesson I. EMF from Chemical Action . . . . . .
Lesson II. Magnetism. . . . . .
Lesson III. Electromagnetic Induction . . . . . .
Lesson IV. AC Voltage . . . . . .
Lesson V. The Uses of AC and DC. . . . . .
Lesson VI. Measuring Voltage. . . . . .

Don't let any of the above new words bother you; they will be explained as you come to them in each lesson. If you find the explanations in the lessons are not clear to you, feel free to ask questions. Now turn the page and begin Lesson I.

BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM

M O D U L E T W O

L E S S O N I

EMF From Chemical Action

Study Booklet

OVERVIEW

LESSON I

EMF From Chemical Action

In addition to the Module Overview, as you start each lesson, you will find a lesson overview such as this page. It is merely an outline of what you will study and learn to do in each lesson. In this lesson you will study and learn about the following:

-force and current
-EMF
-voltage
-sources of EMF

Each of the above topics will be discussed in the order listed. As you proceed through this lesson, observe and follow directions carefully.

BEFORE YOU START THIS LESSON, PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES

LESSON I

EMF From Chemical Action

To learn the material in this lesson, you have the option of choosing, according to your experience and your preferences, any or all of the following:

STUDY BOOKLET:

Lesson Narrative
Programmed Instruction
Lesson Summary

ENRICHMENT MATERIALS:

NAVPERS 93400A-1A "Basic Electricity, Direct Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C : U.S. Government Printing Office, 1965.

Remember, you may study any or all of these that you feel are necessary to answer all Progress Check questions correctly. Do not forget that in one sense of the word your instructor is a living resource, perhaps the best. Call him if you have any kind of a problem.

YOU MAY NOW STUDY ANY OR ALL OF THE RESOURCES LISTED ABOVE. YOU MAY TAKE THE PROGRESS CHECK AT ANY TIME.

NARRATIVE
LESSON 1

EMF From Chemical Action

Force and Current

As you learned in Module One, increasing the force applied to the electrons in a wire causes current flow to increase. From this, you may have concluded that you can change current flow by changing the amount of force applied within the circuit; if so, you were entirely correct; adding more cells in series in a circuit increases the applied force and causes more current to flow.

EMF

The force which moves electrons through the circuit is called EMF. EMF is an abbreviation of electromotive force, which means literally the force which moves electrons. Another name you see and hear frequently is voltage. Voltage, while sometimes abbreviated E, and while also associated with force, actually has a somewhat different meaning than EMF. The basic unit of measurement of EMF is force; however, the unit of voltage is volts.

The values of voltage which you may have to use or measure cover a large range, and the basic unit is very often combined with the metric prefixes micro-, milli-, kilo-, and mega-, so that very small or very large values can be more easily expressed. You will recall that micro- and milli- were discussed in Module One as 10^{-6} and 10^{-3}. The prefix kilo- means 1,000 (10^{3}) and mega- means 1,000,000 (10^{6}). In other words, 1/1,000 of a volt is 1 millivolt, 1/1,000,000 of a volt is 1 microvolt, and 1,000 volts make 1 kilovolt. You can abbreviate these units the same way current values are abbreviated. The letter v (upper or lower case) is used to mean volts; 1,000,000 volts is written 1 Mv. The abbreviation for mega- is the capital letter M and for kilo- it is k (upper or lower case). The following table may help to clarify these values.

Prefix	Abbreviation	Numerical Equivalent	Power of Ten
micro-	μ	$\frac{1}{1,000,000}$	10^{-6}
milli-	m	$\frac{1}{1,000}$	10^{-3}
kilo-	K or k	1,000	10^{3}
mega-	M	1,000,000	10^{6}

Write the following voltages in their most convenient abbreviated form.

a. Thirty thousand volts _____
b. four-thousandths of a volt _____
c. fifteen million volts _____
d. twenty-millionths of a volt _____

Answers: a. 30 kv or 30 KV; b. 4mv; c. 15 Mv; d. 20 μv

Sources

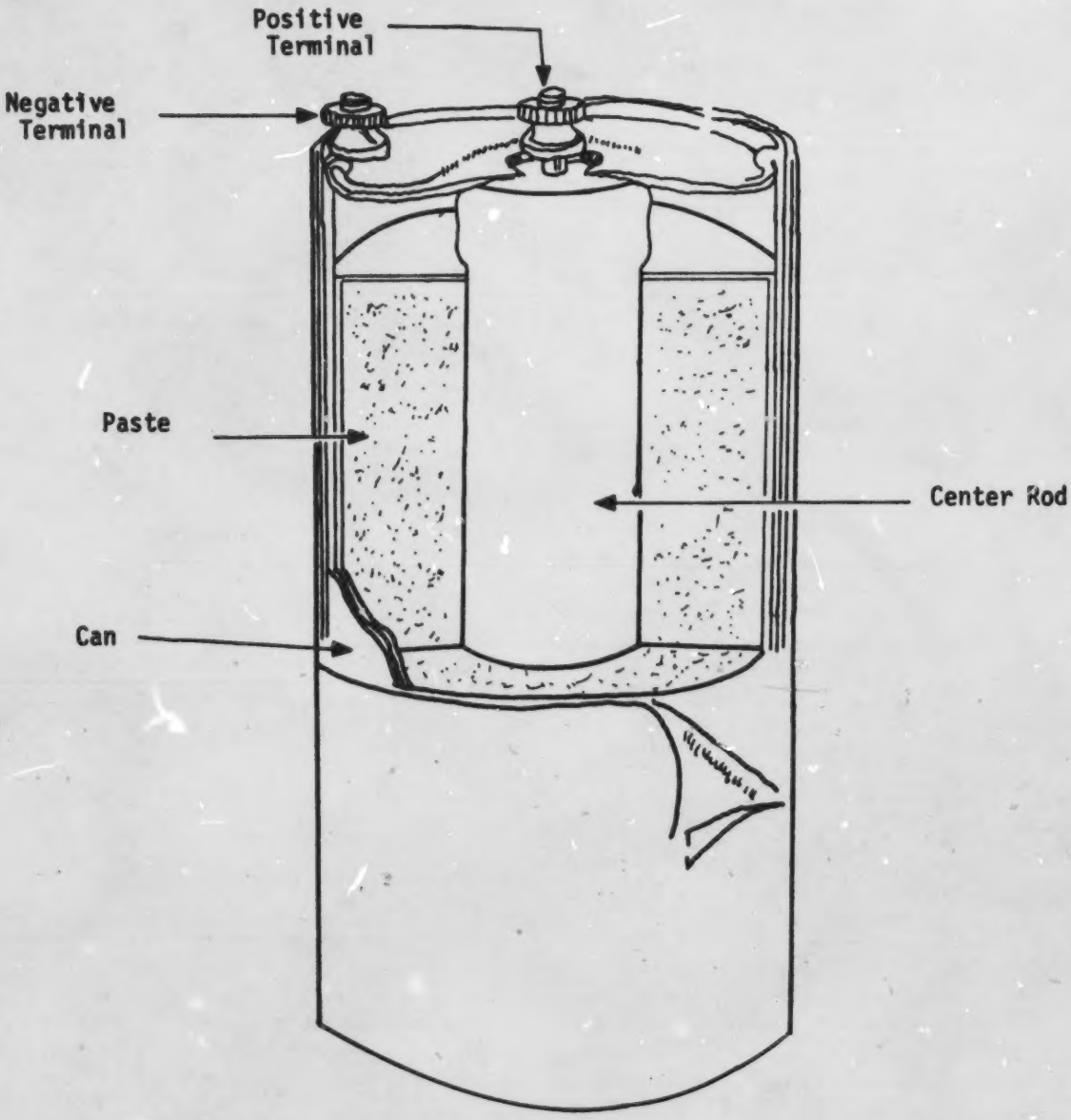
The EMF in the circuit supplies the force to make the electrons do work. Whatever provides electrical force is called a source. So far, you have used two kinds of sources. The dry cell you used in your simple circuit was the source of energy that made the lamp glow.

On the other hand, the source for your power supply is miles away and the energy travels through miles of wire to reach your power supply. While we know where the source for the electrical energy is located in each case and that it causes electrons to do work for us, we still don't know why there is an EMF at the cell connections or at the outlet on the wall.

The Dry Cell as a Source

First, let's study the dry cell. The chemical action inside the dry cell produces the EMF within a cell. In this case chemical energy is converted into electrical energy. Here, as in all other instances, the Law of Conservation of Energy is true. In other words, we can't get something for nothing; we only convert energy from one form into another.

To help you better understand how this conversion takes place, study the illustrated construction of a dry cell on the next page. Observe that this cell is basically a metal can filled with a chemical mixture in the form of a paste and has a rod extending into the paste in the center of the can.

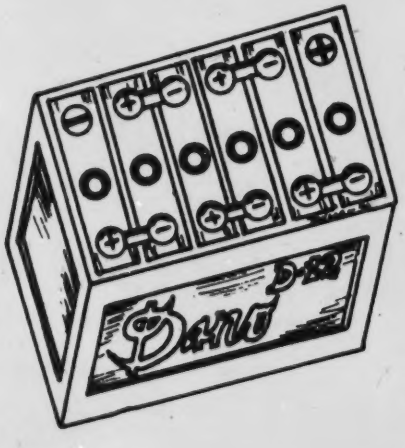


One connection of the dry cell (the negative terminal) is attached to the can or outer case and the other (positive terminal) is connected to the center rod. The rod and the case are of different materials. They react with the chemicals in the paste so that electrons are pulled from the center post and pushed to the outside case. This action occurs until the charges on the cell's terminals balance the chemical forces within the paste. When this condition exists, there is a constant difference of potential or voltage between the case and center rod. Observe that within a cell electrons move from positive to negative - the reverse of what is true in a circuit.

If you connect wires and a lamp to the cell terminals, you provide a continuous path (circuit) for the electrons to move through. The electrons move from the negative case through the circuit to the positive rod in the dry cell. The chemical action moves more electrons from the center post to the case and we have a continuous current flow.

You know, of course, that a cell will eventually wear out and have to be replaced just as in a flashlight or a radio. The chemicals eventually change in form, little current flows, and the cell must be replaced. There are other kinds of cells that can be recharged by reversing the movement of electrons through them; this action restores the original chemical state. This is done by connecting the worn-out or discharged cell to another source.

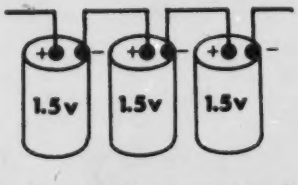
An automobile battery is an example of this kind of cell. (Technically, a battery is a number of cells connected together.) Most automobile batteries today are made up of six cells connected in series, the negative terminal of one connected to the positive terminal of the next, like this:



Connecting Cells in Series

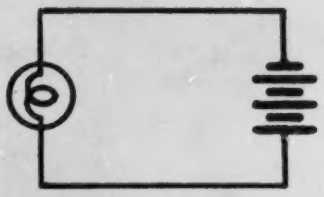
We will learn several ways that cells can be connected, and how the kind of connection affects the source voltage. We will also learn to recognize these connections symbolized schematically.

Cells connected in <u>series</u> are wired together so that the positive terminal of one cell is connected to the negative terminal of another cell. This pictorial illustration shows three 1-1/2-volt cells connected in series, with wires joining + to - or - to +. When cells are connected in series, their individual voltages are additive; thus, we can obtain a greater voltage from the three cells above than we can from just one. In this case, the output voltage will be about 4-1/2 volts.



The total voltage supplied by cells in series is equal to the sum of all the cells' voltages. An example is the kind of cell used in most auto batteries; each cell has an output of 2 volts. Several years ago, cars used a 6-volt electrical system, so three cells were connected in series to get the required voltage. Modern cars use a 12-volt system, and six cells are joined in series to provide the proper voltage for these cars.

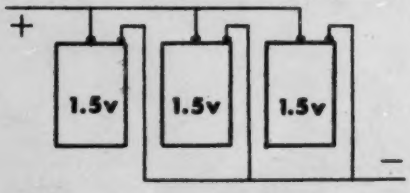
When cells are connected in series, they are represented schematically in this way:



Observe the symbol here shows three cells with positive terminals connected to negative terminals, one right after the other.

Connecting Cells in Parallel

Cells connected in parallel are wired so that like terminals are joined - positive to positive, negative to negative.

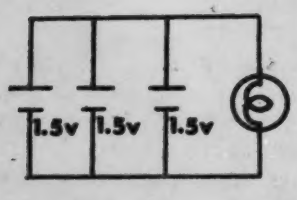


Here is a pictorial illustration of three cells wired in parallel.

When similar cells are wired in parallel, the output voltage of all the cells combined is no greater than the voltage of any single cell. In this case, with three 1-1/2-volt cells connected in parallel, the output voltage is still 1-1/2 volts. Each of the cells contributes to the total 1-1/2 volts, and they tend to share the work load. This serves to prolong the life of the cells.

Parallel connection of cells is often used aboard submarines, where battery power is vital to all ship's operations, and it is desirable to prolong the life of the batteries.

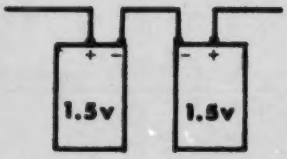
When three cells are connected in parallel, the schematic representation is as shown:



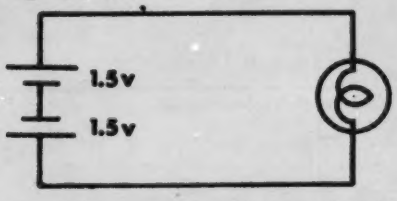
You can see by the symbols that positive terminals are connected together and negative terminals are connected together.

Cells Connected in Series Opposition

A third cell connection is called series opposition, or series opposing. When cells are connected in this manner, they are connected in series - one right after another; however, like terminals are connected together as shown here:

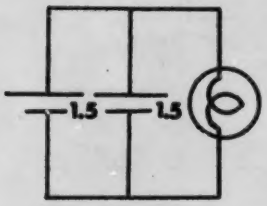


We have seen the utility of cells connected in series, aiding each other. If we incorrectly connect cells in series with wires going between like terminals (positive to positive, and negative to negative), as shown in the schematic,

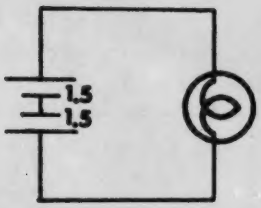


there is no net voltage across the load, and no current flows.

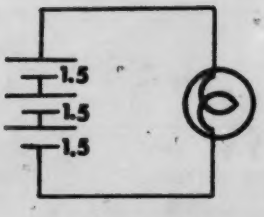
What would the voltage applied to the lamp be for each of these schematics?



1_____



2_____



3_____

Your answers should be:

1. 1.5v (parallel connection)
2. 0v (series opposition connection)
3. 4.5v (series connection)

AT THIS POINT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON I

Voltage

TEST FRAMES ARE 15, 28 and 37. AS BEFORE, GO FIRST TO TEST FRAME 15 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

---

1. Recall that current is caused by the application of an outside force. This force is called EMF, and the EMF leads to an associated voltage.

   Current flow is caused by _____.

- -

(EMF)

---

2. EMF is the force which tends to move electrons. The component which provides this force is called a source. A source is defined as a device which is capable of producing and supplying electrical energy to some type of electrical apparatus. Such sources are sometimes called voltage sources; however, you should be aware that voltage is not the same as EMF.

   Which are examples of voltage sources?

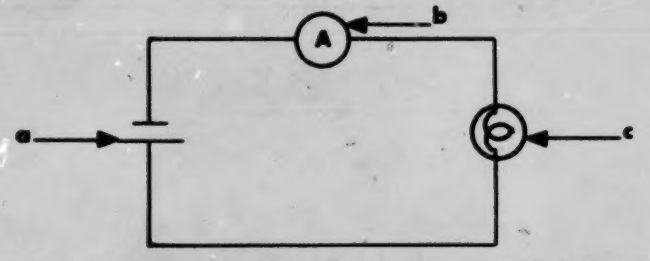
   ___ a. ammeter
   ___ b. dry cell
   ___ c. lamp
   ___ d. power supply

- -

(b. dry cell; d. power supply)

---

3. The lettered arrow that points to the voltage source is:



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(a)

---

4. In a dry cell, the materials contained in the cell react chemically to produce a voltage. In other words, chemical energy is converted into electrical energy.

   Which statement is true?

   ___ a. A voltage is generated by the chemical energy released as a result of mechanical work on the cell.
   ___ b. As a result of chemical action, the cell is capable of delivering electrical energy.
   ___ c. The dry cell is a voltage source because it supplies chemical energy to an external device.

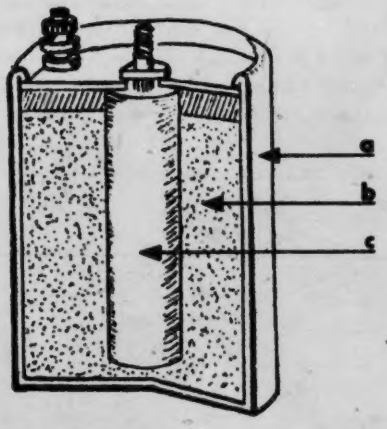
- -

(b) As a result of chemical action, the cell is capable of delivering electrical energy.

5. The most common type of dry cell consists of three basic parts: a zinc can, a chemical mixture in the form of a wet paste, and a center rod or electrode which extends into the paste.

   Match the letters to the terms.

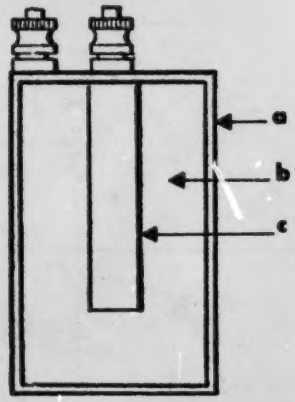
   ___ 1. rod
   ___ 2. zinc
   ___ 3. paste



- -

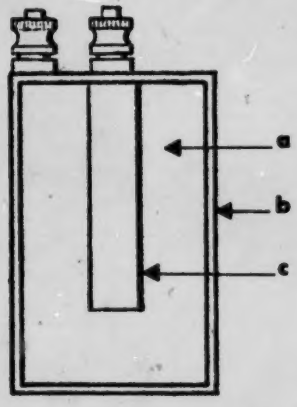
(1-c; 2-a; 3-b)

6. In a dry cell the rod will probably be made of carbon.
Check the lettered arrow that points to the carbon electrode.



(c)

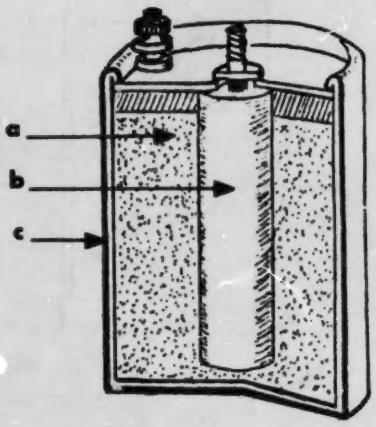
7. The proper name for the zinc container is the zinc electrode.
Check the lettered arrow that points to the zinc electrode.



(b)

8. The chemical mixture or paste packed inside the zinc container (zinc electrode) is called the electrolyte.

   Check the lettered arrow which points to the electrolyte.



(a)

9. Match the following:

___ 1.	can	a. carbon electrode
___ 2.	rod	b. electrolyte
___ 3.	wet paste	c. zinc electrode

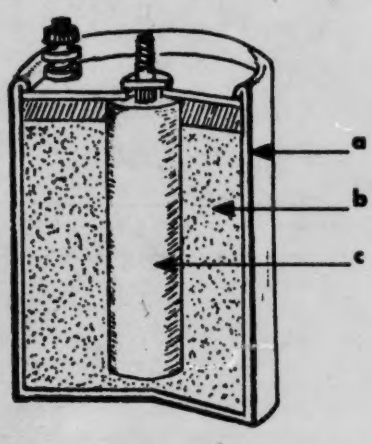
(1-c; 2-a; 3-b)

10. Label the basic parts of the cell according to their proper name.

a. _____

b. _____

c. _____

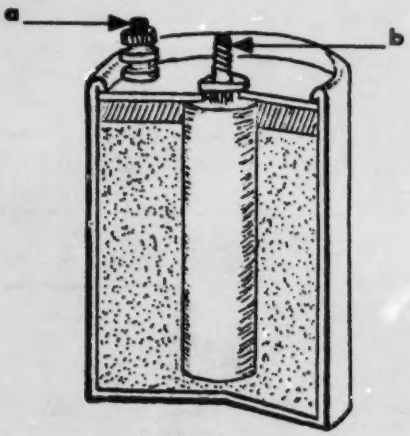


(a. zinc electrode; b. electrolyte; c. carbon electrode)

11. Binding posts or terminals are attached to the electrodes so that wires may be easily connected to the cell. The carbon electrode serves as the positive terminal of the cell and the zinc electrode serves as the negative terminal.

Match the letters to the terms.

___ 1. positive terminal
___ 2. negative terminal

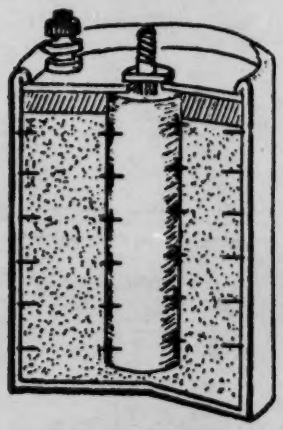


(1-b; 2-a)

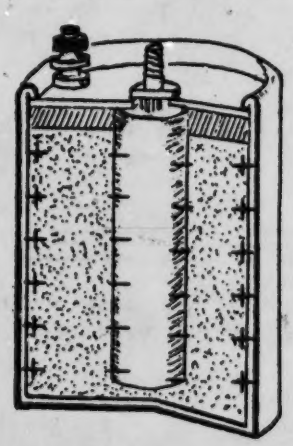
12. The chemical reaction of the carbon and zinc electodes with the paste electrolyte causes an electromotive force (EMF) to be produced. This force separates electrons from atoms within the source and moves the electrons to the negative case. This causes a positive charge to accumulate on the carbon electrode and a negative charge on the zinc electrode.

Which illustration shows the result of the chemical reaction between the electrodes and the electrolyte?

___ a.



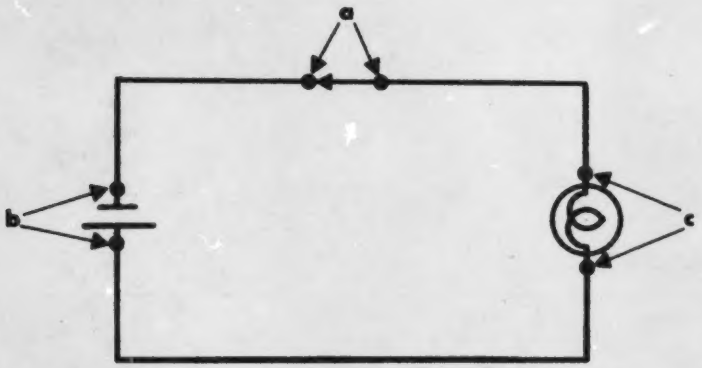
___ b.



(a)

13. When one point (zinc electrode) is more negative than another point (carbon electrode), a difference of potential is said to exist between the two points. A cell then is capable of supplying electrical energy to an external device. In other words, the EMF within a cell causes an electrical potential difference which can cause electrons to move outside the source and do work.

    Which of the following lettered arrows shows a difference of potential due to chemical action?



- - - -

15. Match the following.

___	1.	also called voltage	a. electromotive force
___	2.	chemically produced by the separation and movement of charges, and related to work.	b. potential difference
___	3.	a force which tends to move electrons within a source	

- -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 15

1. b-potential difference

2. b-potential difference

3. a-electromotive force

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 28. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 15 AGAIN.

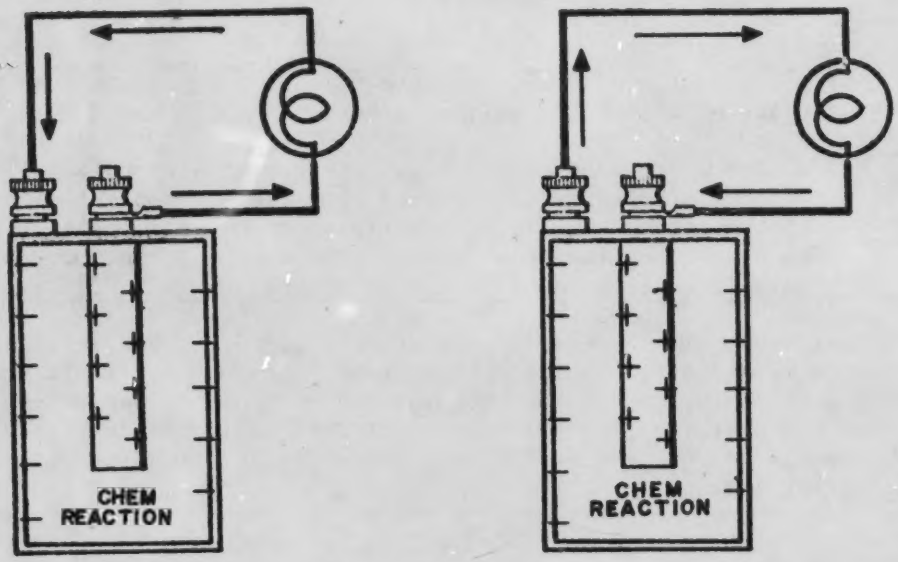
16. As seen, difference of potential is also referred to as voltage. Although EMF, potential difference, and voltage are often used interchangeably, remember that they are actually slightly different in meaning. EMF is a _____. The potential difference which is produced is actually the difference in voltage between the two source points. Note, we can speak of the voltage that exists at any point, as long as we agree on a reference standard. This reference point is always assigned a voltage of zero.

(force)

17. When an external circuit is connected to the source, a path for current flow is provided. The excess electrons at the negative electrode move through the circuit to the positive electrode which is deficient in electrons.

Which illustration shows what occurs when an external circuit is connected to the source?

a. ___ b. ___



- -

(b)

18. Check the statements that are true.

___ a. Current flow outside the source is from positive to negative.
___ b. Current flow inside the source is from positive to negative.
___ c. Current flow outside the source is from negative to positive.
___ d. Current flow inside the source is from negative to positive.

- -

(b. Current flow inside the source is from positive to negative;
c. Current flow outside the source is from negative to positive.)

19. The major drawback of a dry cell is that it eventually loses its ability to produce a potential difference. This occurs because of chemical changes within the cell; remaining chemical energy is no longer converted into electrical energy.

Which is true?

___ a. A dry cell can produce voltage indefinitely and does not have to be replaced.
___ b. A dry cell can produce voltage only as long as the chemical reaction within the cell continues.

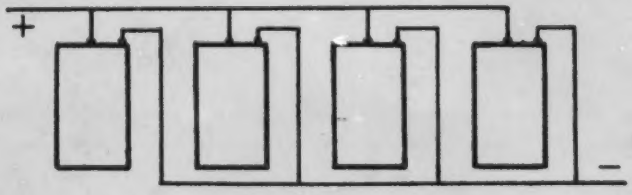
(b) A dry cell can produce voltage only as long as the chemical reaction within the cell continues.

NOTE: There are other kinds of cells such as lead-acid cells, which can be recharged by reversing the movement of electrons through them, rebuilding materials in the cell. This is done by connecting the cell to another source. An automobile battery is an example of this kind of cell.

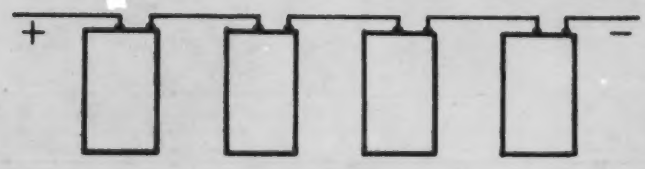
20. Since dry cells have a limited voltage output, there must be some method of obtaining more voltage than that available from one cell - by connecting the negative terminal of one cell to the positive terminal of another cell until the desired voltage is obtained. This type of cell connection is called series aiding.

Which diagram shows a series aiding connection?

___ a.



___ b.



(b)

21. Voltage within a circuit can be increased by adding cells connected in _____.

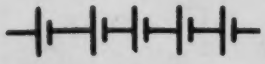
(series aiding)

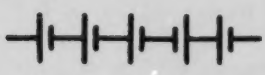
22. A series aiding connection is obtained by:

____ a. connecting the negative terminal of one cell to the positive terminal of another cell.
____ b. connecting the negative terminal of one cell to the negative terminal of another cell.
____ c. connecting the positive terminal of one cell to the positive terminal of another cell.

(a) connecting the negative terminal of one cell to the positive terminal of another cell

23. Which schematic diagram shows the correct series aiding connection of five cells?

____ a. 

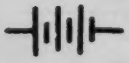
____ b. 

(a)

24. One cell or a combination of cells connected together to provide a voltage greater than an individual cell is called a battery.

Which is the schematic symbol for a battery?

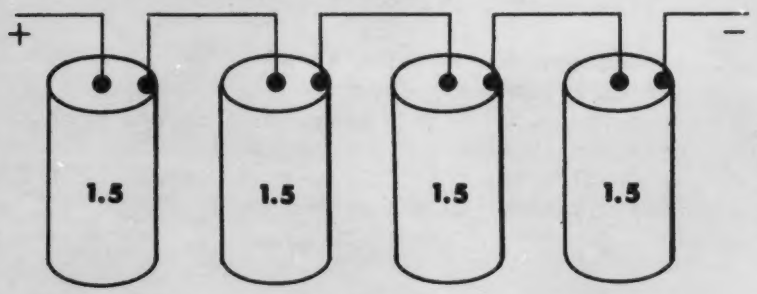
____ a.

____ b. 

(a) (b)

25. The unit of measure for voltage or potential difference is the volt (abbreviated either V or v). When cells are connected in series aiding the total voltage is equal to the sum of the voltages of the individual cells.

What is the maximum voltage that can be obtained from the illustration below?



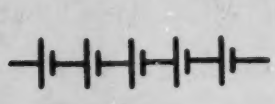
____ volts

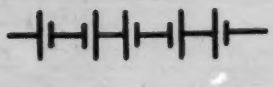
(6 volts)

26. There is another type of series cell connection called series opposing. You must be familiar with series opposing connections although you will rarely see cells deliberately connected in this way. The purpose for learning this concept of cell connections is to prevent confusion when in later modules you deal with voltages that oppose each other.

A series opposing connection is obtained by connecting the negative terminal of one cell to the negative terminal of another cell.

Which schematic diagram shows the correct series opposing connection of five cells?

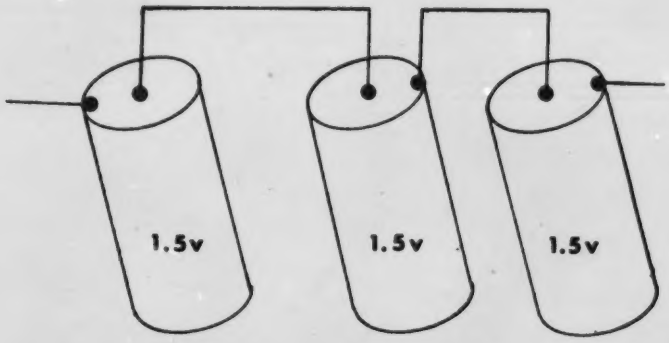
a. 

b. 

(b)

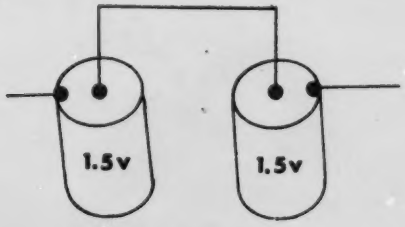
27. When a cell is connected series opposing, its voltage is subtracted from the sum of all voltages connected series aiding to obtain the total voltage available from the combination.

Example:



You will note that two of the cells are connected series aiding and one is connected opposing the two; therefore, the two in series aiding provide 3 v opposing the 1.5 v of the one cell. Total voltage is 3 v - 1.5 v or 1.5 v.

What is the total voltage of the illustration below?



____ volts

- - - -

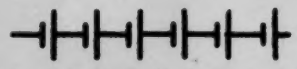
28. Draw a schematic connecting six 1.5v cells to obtain maximum voltage. Label the polarity of each cell also.

What is the output voltage from cells connected as in the schematic you have drawn?

_____

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

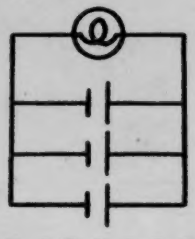
ANSWER - TEST FRAME 28

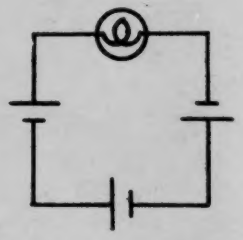
9 volts 

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 37. OTHERWISE, GO BACK TO FRAME 16 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 28 AGAIN.

29. Another type of cell connection is the parallel connection. Cells connected in parallel are wired so that like terminals are joined positive to positive, negative to negative.

Which schematic diagram below shows the correct parallel connection of three cells?

a. 

b. 

(a)

30. When similar cells are wired in parallel, the output voltage of all the cells combined is no greater than the voltage of any single cell.

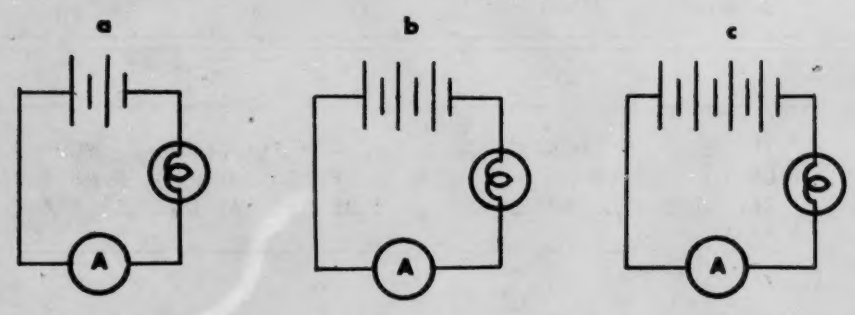
What is the output voltage of the cells below?

(1.5 v)

NOTE: This type of connection serves to prolong the life of the cells because they share the work load. It is often used aboard submarines, where battery power is vital to all ships operations.

31. You will recall from Module One that the greater the force applied the greater the current.

In which circuit would a greater current flow?



(c)

32. You have learned the abbreviations for electromotive force (EMF) and volts (v). Another abbreviation is E, which is used for voltage. (Note: It unfortunately is not the abbreviation for, or the same as, EMF.)

Write the following sentences as mathematical equations using letter abbreviations.

The electromotive force is 9 volts. _____
The circuit has an applied voltage of 60 volts. _____
The voltage in the circuit is equal to 6 volts. _____

(EMF = 9 v; E = 60 v; E = 6v)

33. Match the abbreviations to the appropriate terms.

___ 1.	voltage	a. v
___ 2.	electromotive force	b. E
___ 3.	volt	c. EMF

(1. b-E; 2. c-EMF; 3. a-v)

34. Large values of voltage may be expressed as kilovolts. One kilovolt represents 1000 volts and is symbolized by the letters KV or kv.

50 kv represents _____ v.
3000 v represents _____ kv.
4.5 kv represents _____ v.

(50,000 v; 3 kv; 4,500 v)

35. Small values of voltage may be expressed as millivolts or microvolts.

One millivolt represents 1/1000 of 1 volt or 1×10^{-3} volts and is symbolized by the letters mv.

One microvolt represents 1/1,000,000 of 1 volt or 1×10^{-6} volts and is symbolized by the letters μv.

0.0025 v represents _____ mv; _____ μv
0.0015 v represents _____ mv; _____ μv
0.000005 v represents _____ mv; _____ μv

(2.5 mv; 2500 μv - 1.5 mv; 1500 μv - 0.005 mv; 5 μv)

36. Match the following.

___ 1. 25 kv	a. 25 volts
___ 2. 5 μv	b. 0.025 volts
___ 3. 0.005 v	c. 25 kilovolts
___ 4. 25 mv	d. 5 millivolts
___ 5. 25 v	e. 5 microvolts
___ 6. 0.005 mv	
___ 7. 25,000 v	

(1-c; 2-e; 3-d; 4-b; 5-a; 6-e; 7-c)

37. Match the term to its correct definition or description.

___ 1.	when one point is more negative than another point	a.	voltage source
___ 2.	also called voltage	b.	potential difference
___ 3.	force which moves electrons inside the source	c.	series connection
___ 4.	unit of measure for voltage	d.	volt
___ 5.	capable of producing and supplying electrical energy to some type of electrical apparatus	e.	EMF
___ 6.	two or more cells joined from the negative terminal of one to the positive terminal of another		

- -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN ON THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 37

1. b - potential difference

2. b - potential difference

3. e - EMF

4. d - volt

5. a - voltage source

6. c - series connection

IF ANY OF YOUR ANSWERS ARE INCORRECT, GO BACK TO FRAME 29 AND TAKE THE PROGRAMMED SEQUENCE.

IF YOUR ANSWERS ARE CORRECT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, GO ON TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

SUMMARY
LESSON I

EMF From Chemical Action

As you learned in Module One, a force applied to the electrons in a wire causes current to flow. The subject of this lesson is the force inside the cell which tends to move the electrons to one of the cell's terminals. Electromotive Force, abbreviated EMF, is the technically correct name for this force. Voltage, while sometimes abbreviated E and also associated with force, actually has a somewhat different meaning than EMF.

The basic unit of measurement of EMF is actually force; however, the unit of voltage is that of work per unit charge or simply volts. Because the values of voltage you may use range from very small fractions of a volt to very large numbers of volts, the basic unit is often used with metric prefixes. The most often used prefixes are micro- and milli-, which were covered in Module One, and kilo- (thousand) and mega- (million). The letter V (either upper or lower case) stands for volt, and K (either upper or lower case) means kilo-, so one thousand volts may be written 1 kv. The capital letter M is used for mega-, so 1 MV would be read one megavolt. (Don't confuse this with the Roman number M, meaning one thousand.)

The part of an electric circuit which supplies the EMF is called a source. In the simple circuit of Module One, the source was a dry cell; in your power supply, the source is the generator at the power plant. The dry cell uses chemical action to develop its EMF; the generator converts mechanical action to produce an EMF. Since this lesson is concerned with chemically produced EMF, we will proceed to study the dry cell.

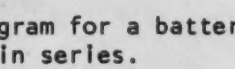
Within a dry cell, the energy produced by the chemical reaction between a paste (electrolyte) and the zinc shell of the cell separates electrons from their atoms and tends to move them to one of the cell terminals. This action results in a force between these electrons at the negative terminal and the positive charges left at the other terminal. The force of the chemical action leads to a difference of potential or voltage between the terminals. When no outside wire connects the terminals of the cell, this difference of potential is a constant value associated with the particular cell.

If a circuit like the one built in Module One is connected to the terminals of the cell, the force (EMF) between the charges on the cell's terminals, as described by Coulomb's Law, will move electrons through the circuit. The continuing chemical action will move more electrons to the negative terminal as fast as they move off into the circuit. In this way a continuous steady current flows.

You know, of course, that the chemicals will eventually change in form, little current will flow, and the dry cell will have to be replaced.

Another kind of cell can be recharged by applying to the cell an outside current flowing in the opposite direction. This reversed current reverses the chemical action. Batteries made of cells which can be recharged are called storage batteries. This kind of battery is used in an automobile. (Note: a battery is just a number of cells connected together.)

Cells are connected together into a battery to provide greater voltage than one cell can supply. The output of cells connected in series is equal to the sum of all the cells' voltages. Since the kind of cell used in a car battery puts out 2 volts, six cells are connected in series to make a 12-volt battery.

The schematic diagram for a battery is:  , showing that the cells are joined in series.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK, OR YOU MAY STUDY THE LESSON NARRATIVE OR THE PROGRAMMED INSTRUCTION OR BOTH. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANOTHER METHOD OF INSTRUCTION UNTIL YOU CAN ANSWER ALL OF THE QUESTIONS CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM

M O D U L E T W O
L E S S O N I I

Magnetism

Study Booklet

OVERVIEW
LESSON II

Magnetism

In this lesson you will study and learn about the following:

- -magnetic fields
- -rules governing lines of force
- -magnetic attraction
- -flux density

Each of the above topics will be discussed in the order listed. As you proceed through this lesson, observe and follow directions carefully.

BEFORE YOU START THIS LESSON, PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON II

Magnetism

To learn the material in this lesson, you have the option of choosing, according to your experience and your preferences, any or all of the following:

STUDY BOOKLET:

Lesson Narrative
Programmed Instruction
Lesson Summary

ENRICHMENT MATERIAL:

NAVPERS 93400A-1A "Basic Electricity, Direct Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.: U.S. Government Printing Office, 1965.

You may study whatever learning materials you feel are necessary to answer the questions in the Lesson Progress Check. All your answers must be correct before you can go to Lesson III. Remember, your instructor is available at all times for any assistance you may need.

YOU MAY NOW STUDY ANY OR ALL OF THE RESOURCES LISTED ABOVE. YOU MAY TAKE THE PROGRESS CHECK AT ANY TIME.

NARRATIVE
LESSON 11

Magnetism

Why Study Magnetism

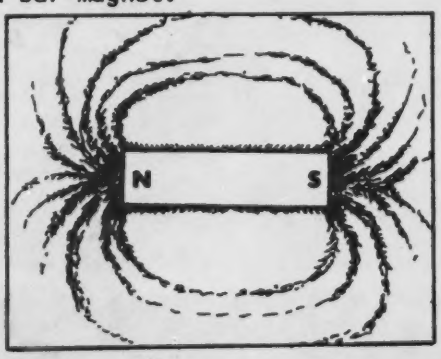
Let us now consider in greater detail the source of the voltage available at a wall electrical outlet. This potential difference is delivered from a power plant through many miles of wires to your work table. At the power plant, huge generators convert mechanical energy into electrical energy through magnetism. (Remember that a cell converts chemical energy into electrical energy.)

Generators supply all the electrical needs on board ships also. The caring for these generators and the switching systems that route their output to all parts of a ship is the job of the EM; however, personnel of all ratings trained in this course depend upon and work with the electricity generated. To understand what happens inside a generator you need to know something about magnetism because this is one of the basic factors involved in the conversion of mechanical energy into electricity.

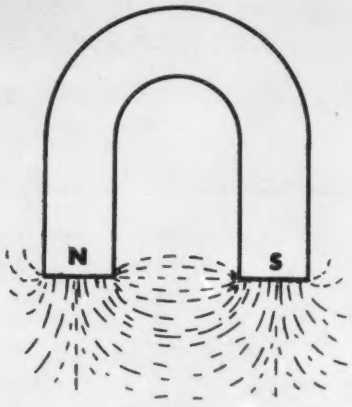
No one knows the full details as to what causes magnetism, but we can see how it works and what it does. You have probably seen magnets and know that they can pull some things to them. If you've played with two magnets, you know that they sometimes attract and sometimes repel each other.

Magnetic Field

To explain the things a magnet does, scientists use a concept called lines of flux or lines of force. These are imaginary lines; you cannot see them. They represent magnetic force. The lines of flux around a magnet make up a pattern called a magnetic field. The effects of this force pattern can be shown by placing a sheet of glass on a magnet lying on a flat surface. Iron filings sprinkled on the glass will settle in a pattern of lines just like the flux lines. Here is a drawing of the flux pattern (magnetic field) around a bar magnet:



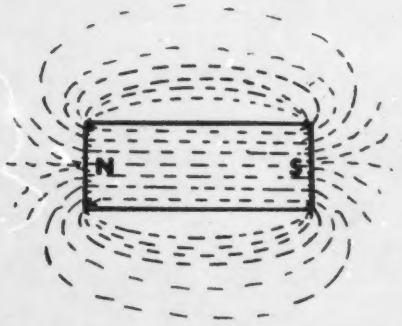
The magnetic field around a horeshoe magnet, as indicated by the iron filings, looks like this:



Rules Governing Lines of Force

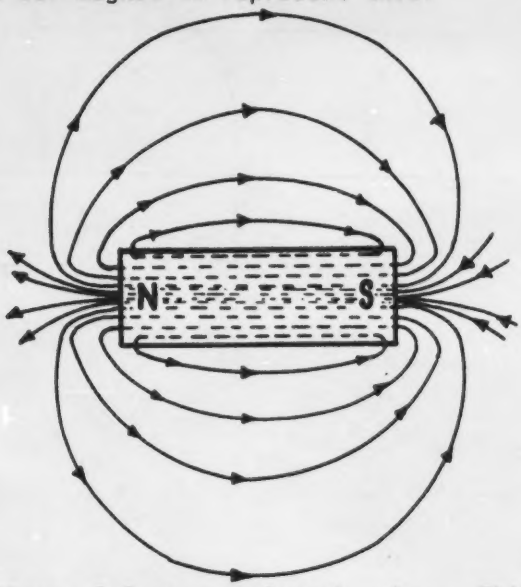
Lines of flux were devised as a way to explain magnetism. Scientists have discovered certain rules that seem to explain lines of flux.

1. Magnetic lines of force always form complete loops. Part of each loop is always within the material of the magnet. Look again at the pattern for a bar magnet:



2. Magnetic lines of force have polarity. This means they have a direction. The ends of the bar magnet are designated N (or North) and S (or South). By definition the lines of flux travel through a magnet internally, from the South Pole to the North Pole; and externally always leave the (N)

Pole and enter the (S) Pole even though they do not actually flow like a stream. We can add arrowheads to the magnetic field of a bar magnet to represent this.



3. Magnetic lines of force repel each other. This, together with Rule 1, that they always form closed loops, means that lines of force will never cross.

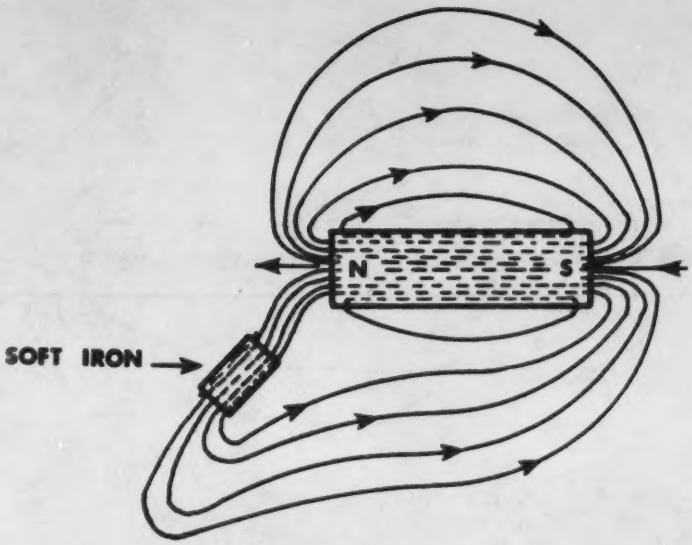
4. Magnetic lines of force always try to form the smallest possible loop. All the lines of force around a magnet would contract right down to the surface of the magnet if they did not tend to repel each other. The balance of the two forces (contraction and repulsion) result in the patterns previously shown.

5. Magnetic lines of force pass through any kind of material. There is no known substance that lines of force cannot enter. There are some materials that they will enter into or follow much more readily than others, but there are none which will block their passage.

6. Magnetic lines of force always enter or leave a magnet perpendicular to its surface. In the case of the bar magnet, most of the lines of force enter and leave the magnet at right angles to its ends, but some still leave at right angles to each side.

Magnetic Attraction

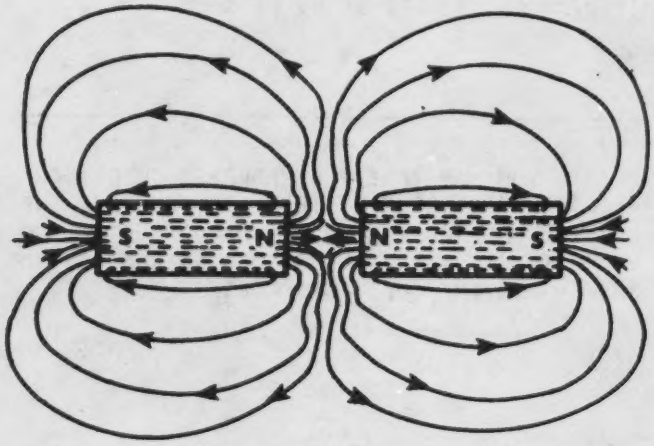
Magnets attract certain objects to them because these objects offer an easier path for the lines of force. These objects are magnetic materials, and they usually contain iron, nickel, or cobalt. Some of the magnetic lines of force enter these objects rather than air, and this distorts the usual magnetic field as shown in the figure on the following page.



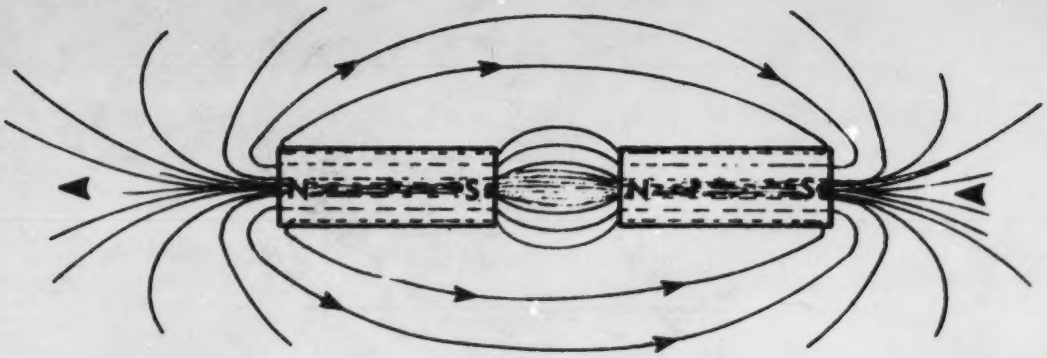
The tendency is for the lines of force to try to contract (Rule 4) but still pass through the magnetic substance, and the substance is pulled to the magnet. Alternatively, we can think of the lines of force converting the magnetic material (here the soft iron) into another magnet. Let's see how this works.

If two bar magnets are placed end to end with two like poles together (both N poles or both S poles), the lines of force will repel each other and will cause the magnets to try to push apart.

LIKE POLES REPEL



However, if one of the magnets is turned so that one N pole and one S pole are brought together, the fields from each magnet join; the lines of force pass through both magnets, and the magnets are drawn together so that their fields reinforce each other. (This explains the action of the soft iron in the earlier figure; it behaves like a magnet with its newly formed S pole close to the N pole of the permanent bar magnet.)



UNLIKE POLES ATTRACT

Flux Density

The total strength of the magnetic field is indicated by the flux. A strong field has many lines of flux, but a weak field contains few lines of flux. A measure of the magnetic field at any point is the flux density. Flux density refers to the number of lines of force present through any unit of area perpendicular to the field. We might have a square inch with just one line of force (low flux density) at some distance from a magnet, but near a pole (end), the magnet might have a flux density of tens of flux lines crossing one-hundredth of a square inch. As you can see from the pattern of flux lines around a magnet, the flux density is greatest at the poles of the magnet.

AT THIS POINT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON II

Magnetism

TEST FRAMES ARE 41 AND 45. AS BEFORE, GO FIRST TO TEST FRAME 41 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. You have learned that one method of producing an EMF is by chemical action.

   Producing an EMF by chemical action is employed in a component called a _____ or _____. (Either order)

(cell or battery)

2. Looking at your power supply you can see that it receives its energy without requiring a cell or battery. This energy is produced far away by converting mechanical energy into electrical energy utilizing magnetism.

   The voltage for your power supply is produced utilizing _____.

(Magnetism)

3. For our purposes, magnetism is the property of some metals to be attracted by a nearby magnet.

   If a metal is attracted by a magnet, the force of attraction is indicative of _____.

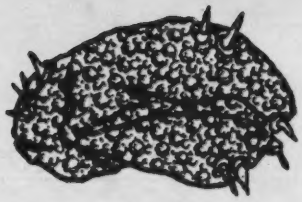
(magnetism)

4. All matter can be classified as either magnetic or nonmagnetic. Metals that are strongly attracted by a magnet are classified as magnetic. All other matter is classified as nonmagnetic.

   A wooden pencil is a form of _____ material.

(nonmagnetic)

5.



NATURAL **ARTIFICIAL**

A natural magnet and the so-called artificial magnet are our two sources of magnetism. The two sources of magnetism are the _____ magnet and the _____ magnet. (either order)

- -

_____

(natural - artificial)

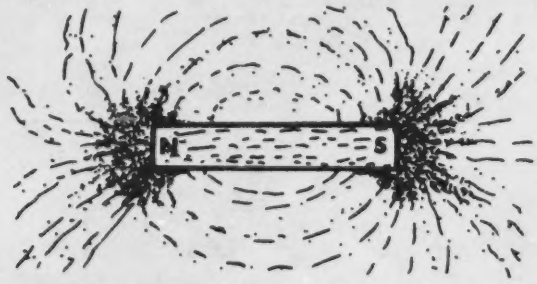
6. We seldom use natural magnets today, because we can produce much better and cheaper artificial magnets. All man-made magnets are classified as _____ magnets.

- -

_____

(artificial)

7. The poles of a magnet are the ends where most of the magnet force is concentrated. If a magnet is sprinkled with iron filings, most of the filings will be attracted to and collected at the poles. If you sprinkle iron filings in the area around a magnet, you will notice that the filings collect in a definite pattern. This pattern is caused by an invisible magnetic field, and its associated magnetic force, that surrounds all magnets.



The magnetic field concentrates around the end of the magnets called _____.

- -

_____

(poles)

8. The lines formed by the magnetic field are called magnetic lines of flux (also called lines of force); a definite, measurable force exists between these lines and any magnetic material.

   The magnetic force associated with a magnet defines an invisible magnetic _____ that surrounds all magnets.

- -

(field)

9. The _____ within the magnetic field are called magnetic lines of flux.

- -

(lines)

10. Magnetic lines of flux are concentrated at the _____ of the magnet.

- -

(poles or ends)

11. A magnetic field is generally measured in terms of flux density. Flux density is the ratio of the number of magnetic lines of flux, passing through an area perpendicular to the lines of force and is expressed as the number of lines of flux per unit of area (expressed in square inches or square centimeters). The number of lines of flux in each unit of area is the _____.

- -

(flux density)

12. Flux density is the ratio of the _____ of flux to the size of the perpendicular area.

- -

(number of magnetic lines)

13. The greatest flux density occurs at the _____ of a magnet.

- -

(poles)

14. Flux density is the number of magnetic lines of flux in _____ _____ of area.

(each unit)

15. Flux density is _____.

(the number of lines of magnetic flux in each unit of area)

16. The compass that you used as a Boy Scout or camper had a permanent magnet as its needle. The end of the needle that is attracted to the north pole of the Earth was at one time called the north seeking pole. Today, the word seeking has been dropped; it is called the north pole of the magnet.

    Any magnet that is suspended, and is free to turn, will align itself with the Earth's magnetic field. The end of the magnet that points to the north is the _____ pole of the magnet.

(north)

17. The end of the magnet that points to the south is the _____ _____ of the magnet.

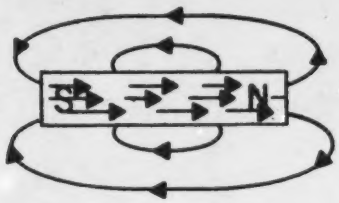
(south pole)

18. The greatest flux density occurs at the _____ of the magnet.

(poles)

19. There are six rules for magnetic flux that you should know. The first rule is:

    Inside a magnet, the direction of the flux lines is from the south pole to the north pole.



Inside the magnet, lines of flux run towards the _____ pole and away from the _____ pole.

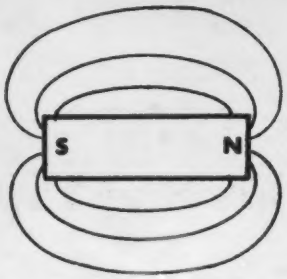
(north - south)

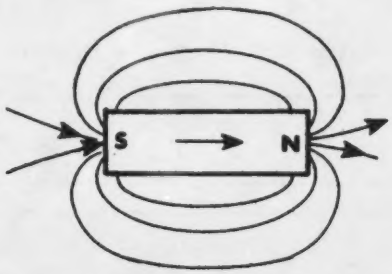
20. Magnetic lines of flux are directional. Outside a magnet, by definition magnetic flux lines always leave the north pole and always enter the south pole.

    The direction of magnetic lines of flux outside a magnet is from the _____ pole to the _____ pole.

(north - south)

21. Using arrows, indicate on the following magnetic field the direction of magnetic lines of flux - both inside and outside the magnet.

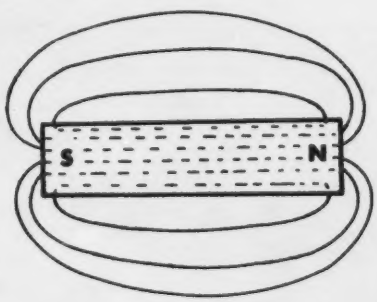




22. State the rule pertaining to the direction of magnetic flux lines.

(Lines of flux travel from north to south outside the magnet and from south to north inside the magnet.)

23. An electrical circuit forms a complete path for current flow; a magnetic circuit forms a <u>closed</u> loop for each line of flux.



Thus we have stated the second rule.

Magnetic lines of flux form _____ loops.

(closed)

24. Flux lines are never broken. Their path may be altered by an outside force, causing the shape of the magnetic field to change, but each line of force will remain unbroken, each forming a _____ _____.

(closed loop)

25. Write true or false before each statement.

___ a. Lines of flux form incomplete loops.
___ b. Lines of flux form closed loops.
___ c. Lines of flux follow a straight path.

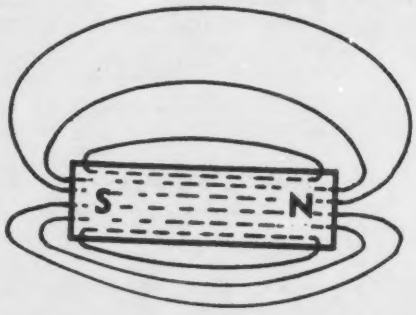
(a. false; b. true; c. false)

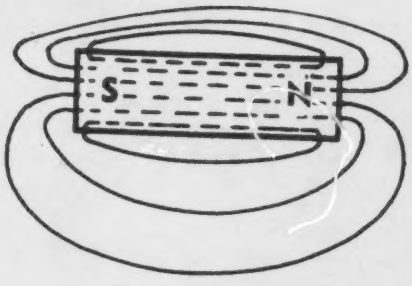
26. For the third rule, we find that lines of force polarized in the same direction repel each other. This repulsion is what gives the magnetic field its expanded, uniform, or symmetrical pattern.

In a magentic field, the individual lines of force of the same polarization _____ each other.

(repel)

27. Check the lines-of-flux rule which correctly identifies the diagrams.





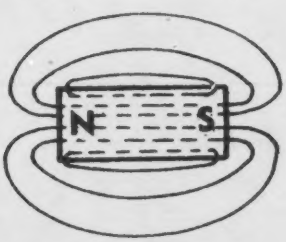
___ a. Lines of flux move in haphazard directions.
___ b. Magnetic lines of force cross each other.
___ c. Flux lines polarized the same repel each other.
___ d. Flux lines in the same direction attract each other.

(c) Flux lines polarized the same repel each other

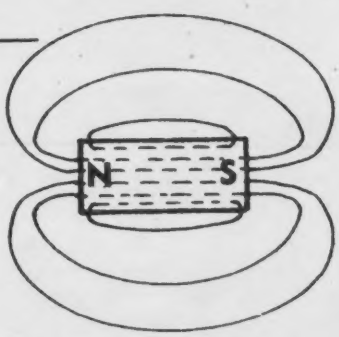
28. The fourth rule of flux lines is that lines of force tend to make themselves as short as possible.

Select the drawing which most correctly shows the flux lines around a magnet.

a. ___



b. ___



(a)

29. Write true or false.

_____ a. Lines of flux tend to expand.
_____ b. Lines of flux tend to contract.
_____ c. Lines of flux always travel long distances.

(a. false; b. true; c. false)

30. The fifth rule of flux lines is that there is no known substance which will stop the lines of force.

Which of the following could be used to block lines of flux?

___ a. soft iron
___ b. cobalt
___ c. a copper shield
___ d. none of the above

(d) none of the above

31. Simply stated, magnetic lines of flux will pass through all material.

Magnetic lines of flux will pass _____ ___ _____.

(through all material)

32. State the rule about insulation from flux lines.

_____ _____
_____

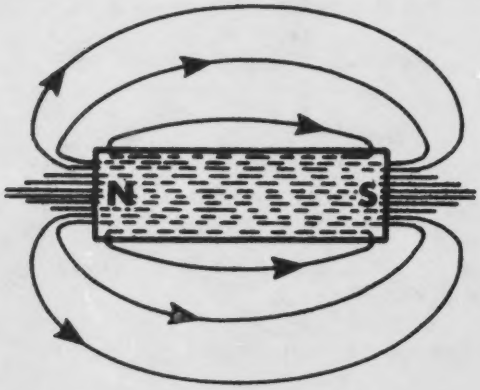
(Magnetic flux lines pass through all material.)

33. The last of the six rules is that flux lines always enter or leave a magnet perpendicular to its surface.

Lines of flux always _____ or _____ a _____ at right angles to its surface.

(enter - leave - magnet)

34. Check the lines-of-flux rule which correctly identifies the diagram.



___ a. Like poles attract each other.
___ b. Lines of flux always enter and leave the poles at right angles.
___ c. Like poles repel each other.

(b) Lines of flux always enter and leave the poles at right angles.

35. We have just covered the six rules pertaining to magnetic flux lines. Let's review them again quickly.

Magnetic flux lines always form _____ _____.

(closed loops)

36. Lines of flux travel from _____ to _____ outside a magnet.

(north - south)

37. Similar magnetic lines of force _____ each other.
repel/attract

(repel)

38. Magnetic lines of force always form the _____ loops possible.

_____
(smallest)

39. Magnetic lines of force pass _____ ____ _____.

_____
(through all material)

40. Magnetic lines of force enter and leave a magnet at _____ _____.

_____
(right angles or perpendicular to the surface)

41. State the six rules pertaining to magnetic flux lines.

Magnetic flux lines always:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

_____

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 41 *

1. Form closed loops.
2. Leave the north pole and enter the south pole.
3. Repel each other.
4. Try to form the smallest possible loop.
5. Pass through any material.
6. Enter or leave a magnet perpendicular to its surface.

* Answers may be in any order

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 45. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 41 AGAIN.

42. Before we complete this lesson, let's take up the two laws of magnetic poles for magnetism:

    - Like poles repel each other.
    - Unlike poles attract each other.

    Consider two permanent magnets. If you try to put the two north poles together, they will _____ each other.

(repel)

43. If the north pole and south pole are placed together, they will _____ each other.

(attract)

44. As we said before, these are known as the law of magnetic poles for magnetism.

    a. like poles _____.
    b. unlike poles _____.

- -

(a. like poles repel; b. unlike poles attract)

45. State the laws of magnetic poles.

_____

_____

- -

_____

(THIS IS A TEST FRAME. COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 45

Like poles repel,

unlike poles attract.

IF YOUR ANSWER IS INCORRECT, GO BACK TO FRAME 42 AND TAKE THE PROGRAMMED SEQUENCE.

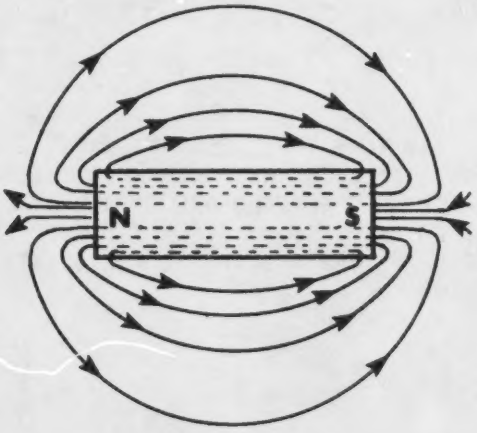
IF YOUR ANSWER IS CORRECT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, GO ON TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

SUMMARY
LESSON 11

Magnetism

In the last lesson you studied the generation of an EMF by chemical action; now you will take the first step in learning about how generators convert mechanical energy into EMF. Since magnetism is an essential element in this conversion process, you must know some of its characteristics before you can learn how generators work.

Lines of flux or lines of force are imaginary lines used to represent the very real magnetic field and its associated force. This concept helps us to explain why magnetism acts as it does. A magnet is surrounded by lines of force or lines of flux which can be detected; the pattern formed is called a magnetic field.



The shape of this field and some of its effects are explained by six basic rules:

1. Lines of magnetic force always form complete loops.
2. Lines of magnetic force are polarized. By agreement, they are directed out of the N pole and into the S pole of a magnet.
3. Magnetic lines of force polarized in the same direction tend to repel each other.
4. Magnetic flux lines always try to form the smallest possible loop.
5. Magnetic lines of flux occur in any material. There is no known insulator against them.
6. Magnetic lines of flux always enter or leave a magnet at right angles close to its surface.

Magnets attract certain materials to them. Examples of these magnetic materials are iron, nickel, and cobalt. Most magnetic materials contain

one or more of these three elements.

Two magnets will also attract each other if they are placed near each other with opposite (N and S) poles close together, but they will repel each other if one of them is turned around (N and N or S and S). The law which states this effect is similar to that indicated by Coulomb's Law. It is called the law of magnetic poles and is stated as: Like poles repel; unlike poles attract.

The amount of force (attraction or repulsion) a magnet can exert depends on the strength of its magnetic field. The strength of the magnetic field at any point is indicated by the flux density. Flux density is the number of lines of force per unit area perpendicular to the field, and will vary with the distance from a magnetic pole. Flux density for any magnet is always greatest at its poles, and decreases as distance from the poles increases, again in a manner similar to that described by Coulomb's Law for charges.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK, OR YOU MAY STUDY THE LESSON NARRATIVE OR THE PROGRAMMED INSTRUCTION OR BOTH. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANOTHER METHOD OF INSTRUCTION UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM

M O D U L E T W O

L E S S O N I I I

Electromagnetic Induction

Study Booklet

OVERVIEW
LESSON III
Electromagnetic Induction

In this lesson you will study and learn about the following:

- -left-hand rule for generators
- -magnetic mechanical generation

Each of the above topics will be discussed in the order listed. As you proceed through this lesson, observe and follow directions carefully.

BEFORE YOU START THIS LESSON, PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES

LESSON III

Electromagnetic Induction

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following:

STUDY BOOKLET:

Lesson Narrative
Programmed Instruction
Lesson Summary

ENRICHMENT MATERIAL:

NAVPERS 93400A-1a "Basic Electricity, Direct Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.; U.S. Government Printing Office, 1965.

AUDIO-VISUAL:

Sound/Slide - "Electromagnetic Induction"

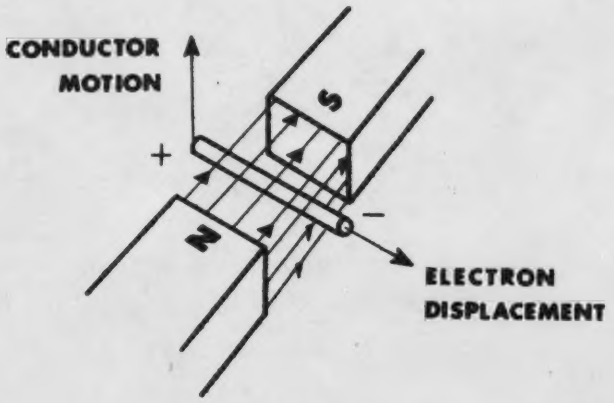
Remember, you may study any or all of these that you feel are necessary to answer all Progress Check questions correctly. Do not forget that in one sense of the word your instructor is a living resource; perhaps the best. Call him if you have any kind of a problem.

YOU MAY NOW STUDY ANY OR ALL OF THE RESOURCES LISTED ABOVE. YOU MAY TAKE THE PROGRESS CHECK AT ANY TIME.

NARRATIVE
LESSON III

Electromagnetic Induction

Electromagnetic induction is the action that causes electron displacement in a conductor when the conductor moves relative to a magnetic field so that it cuts through lines of force. In other words, if a piece of wire is moved in a magnetic field, as shown below, the motion of the lines of flux past the electrons in the wire tends to push the electrons toward one end of the wire. This places a greater number of electrons at one end of the wire than the other. The concentration of electrons tends to form a negative charge at one end of the wire and leaves the other end with too few electrons (or positively charged).



Relative Motion

We use the term relative motion to indicate that motion is taking place between the conductor and the lines of flux in such a manner that flux lines are being cut. The conductor may be stationary and the field moving or the field may be stationary and the conductor moving. Both the conductor and field may be in motion. In any of these cases motion occurs relative to either the field or the conductor which results in flux lines being cut. For electromagnetic induction to take place, relative motion must be present.

The Left-Hand Rule

This concentration of charges or voltage is an induced EMF, and its polarity may be determined by using the thumb, index finger, and middle finger of your left hand as follows:

1. Hold your thumb so that it points in the same direction the conductor is moving.

2. Point your index finger (forefinger) in the direction of the flux lines, from N pole to S pole of the magnet. Your hand should now look like a play gun.

3. Now, keeping your thumb and forefinger in this position, point your middle finger straight out from the palm of your hand, as shown below, and it will point in the direction of the electron movement in the wire.

You may have to turn you hand around, sometimes into some very awkward positions, to get it lined up properly with the movement of the wire and the direction of the magnetic field.

Magnetic-Mechanical Generation

The generators (alternators) in large power plants, aboard ship, and in your car change mechanical energy into electrical energy through electromagnetic induction. Generators must supply the huge amounts of energy needed to run a modern city or ship.

The amount of EMF generated varies according to the following factors:

1. The strength of the magentic field. A weak magnet will produce few flux lines; a strong magnet, many flux lines.

One flux line pushing one electron as it contacts the electron always produces the same amount of force, so if more lines of flux are present to push more electrons, a greater total force will be developed.

2. The speed of relative motion between the flux lines and the conductor. This is closely related to the first factor; the faster the motion, the greater the number of flux lines pushing electrons in a given time, and the greater the EMF produced in that given time.

3. The length of wire in the magnetic field. A longer wire in the magnetic field will cause more electrons to be pushed by the lines of force, and more EMF will result. In most generators, wire is formed into coils or loops. This coil contains many turns, thereby allowing a long wire to be placed in a small space in a generator.

   The magnetic field is concentrated in this small space, thus producing a strong electrical output if the coil is rapidly moved.

AT THIS POINT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON III

Electromagnetic Induction

TEST FRAMES ARE 17, 22 AND 26. AS BEFORE, GO FIRST TO TEST FRAME 17 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. Definition of electromagnetic induction: Electromagnetic induction is the action which causes electron displacement in a conductor when the conductor moves relative to a magnetic field and cuts through lines of force.

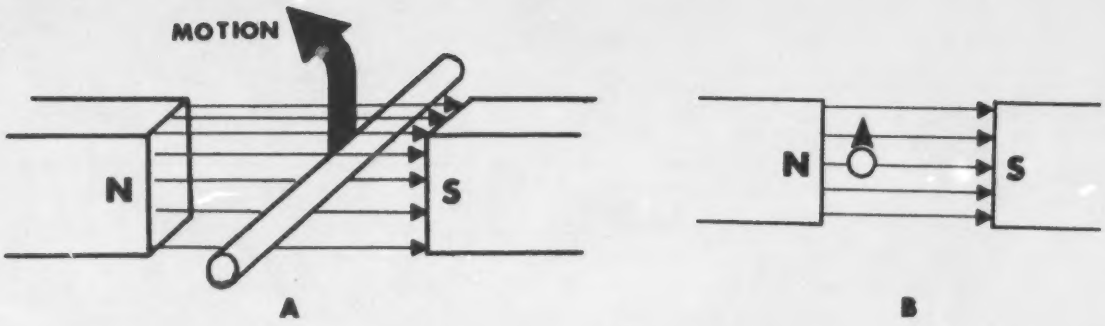
   An EMF is produced by moving a conductor through a _____.

(magnetic field)

2. State the definition of electromagnetic induction.

(The action which causes electron displacement in a conductor when it moves relative to a magnetic field and cuts through lines of force.)

3.

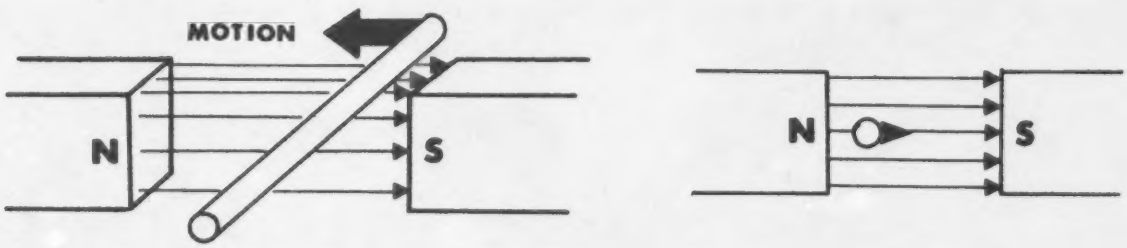


Figures "A" and "B" show a conductor cutting lines of a magnetic field. The end view of the conductor in part B shows the conductor moving at right angles to the magnetic field.

Is there an induced EMF in the moving conductor? _____

(yes)

4.

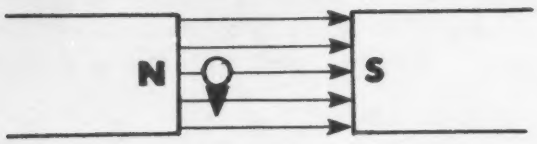


Now the conductor is moving parallel to the lines of force. The conductor does not cut lines of force.

Is there an induced EMF in the conductor? _____

(no)

5.



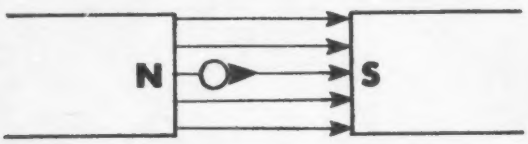
Again the conductor is cutting the lines of force at a right angle. This time the conductor is moving _____.
down/up

(down)

6. Is there an induced EMF in the moving conductor in frame 5? _____

(yes)

7.



Now the conductor is moving parallel to the lines of force.

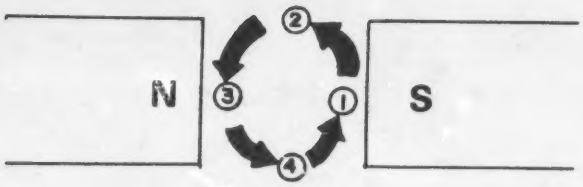
Does the conductor cut lines of force? _____

(no)

8. Is there a voltage induced in the conductor in frame 7? _____

(no)

9.



The figure shows four positions of the conductor in a magnetic field. The conductors are moving as shown by the arrows.

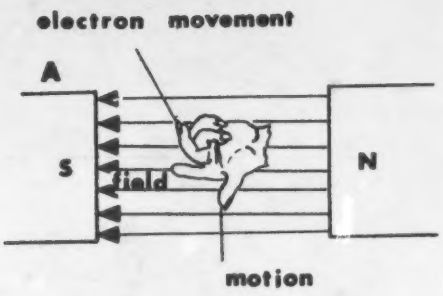
a. In which position or positions is an EMF induced in the conductor? _____
b. In which position or positions is no EMF induced in the conductor? _____
c. The only time a voltage is induced in a conductor is when the conductor is:

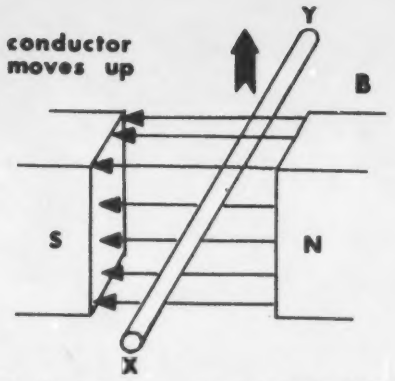
____ 1. moving parallel to the lines of force.
____ 2. cutting the lines of force.

- -

(a. 1 and 3; b. 2 and 4; c. 2.)

10.





The direction of electron movement is found by using the left-hand rule for generators.

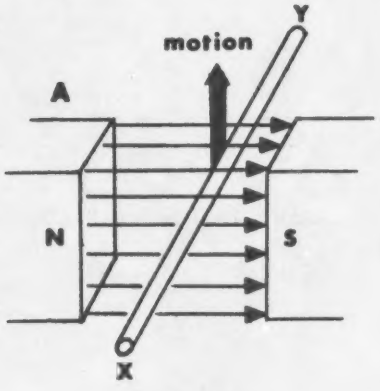
Here's how you use the rule. Place the thumb, first and middle fingers of the left hand all at right angles to each other as in Figure A.

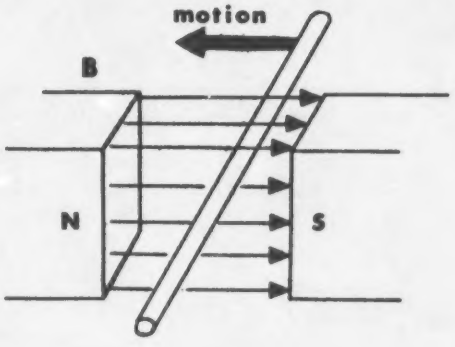
a. The thumb points in the direction in which the conductor is moving.
b. The first finger points in the direction of the flux lines.
c. The middle finger points in the direction of electron movement.

By using the left-hand rule for generators, determine whether the direction of electron movement in Figure B above is toward X or Y.

(Y)

11.





a. The conductor in Figure A is cutting lines of force at a right angle.
b. The conductor in Figure B is moving parallel to the lines of force.

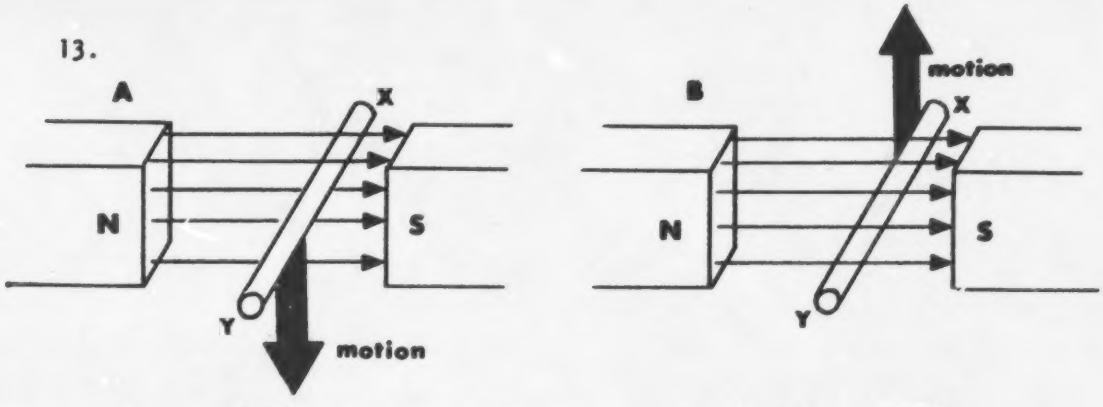
Which conductor will have an induced EMF? _____

(A)

12. Using the left-hand rule for generators, determine whether the direction of electron movement in Figure A Frame #11 is towards X or Y.

(X)

13.



The conductor in Figure A above is moving down through the magnetic field. The polarity of the induced voltage at point Y is positive.

In Figure B above, the conductor is moving up. What is the polarity of the induced voltage at point Y with respect to point X?

___ a. positive
___ b. negative

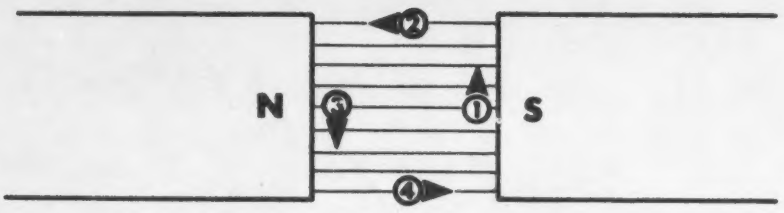
(b) negative

14. What is the direction of electron movement in Figure B above? Toward:

___ a. X
___ b. Y

(b) Y

15.



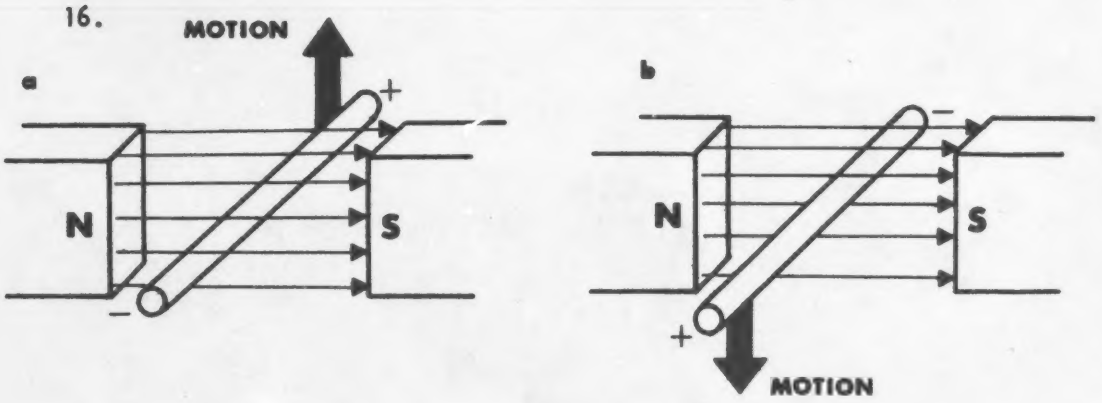
The illustration shows four positions of the conductor. A voltage is induced in the conductor when the conductor is moving as in 1 and 3.

How do the polarities of induced voltage in Positions 1 and 3 compare?

___ a. same
___ b. opposite

(b) opposite

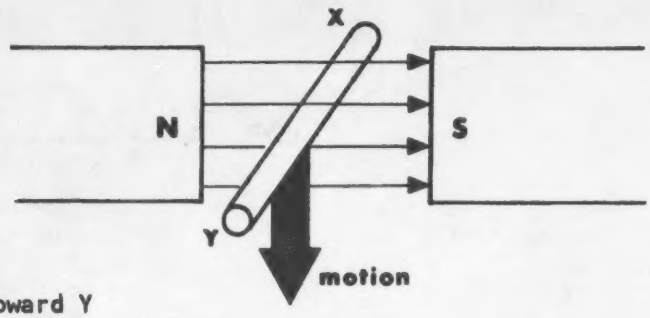
16.



The illustrations show that when the conductor changes its direction through the magnetic field, the _____ of the induced voltage changes.

(polarity)

17. What is the direction of electron movement in this figure?



___ a. Toward Y

___ b. Toward X

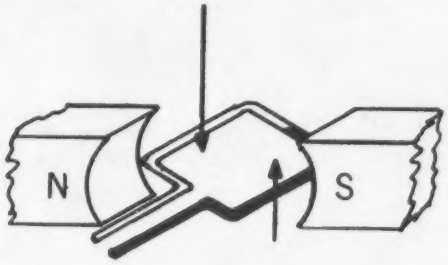
(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 17

a. Toward X

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 22. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 17 AGAIN.

18.



The illustration shows the conductor formed into a loop or coil.

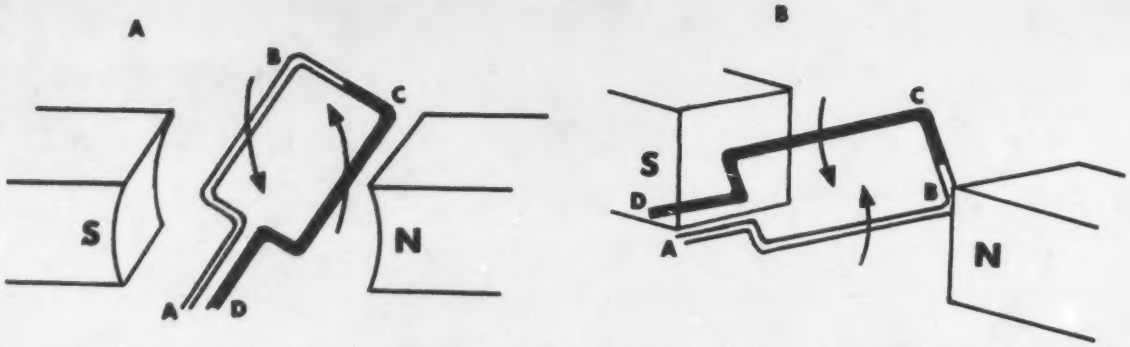
When the black side is moving up, the white side is moving _____.

(down)

19. The voltage induced in the black side _____ the voltage induced in the white side.
aids/opposes

(aids)

20.



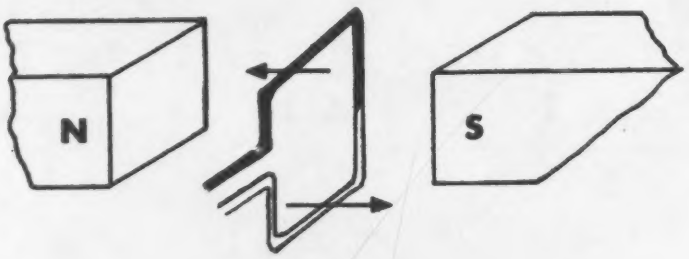
In Figure A above, point D is positive with respect to point C.

a. In Figure B, point D is _____ with respect to point C.
b. In Figure A, point A is _____ with respect to point B.
c. In Figure B, point A is _____ with respect to point B.

- -

(a. negative; b. negative; c. positive)

21.



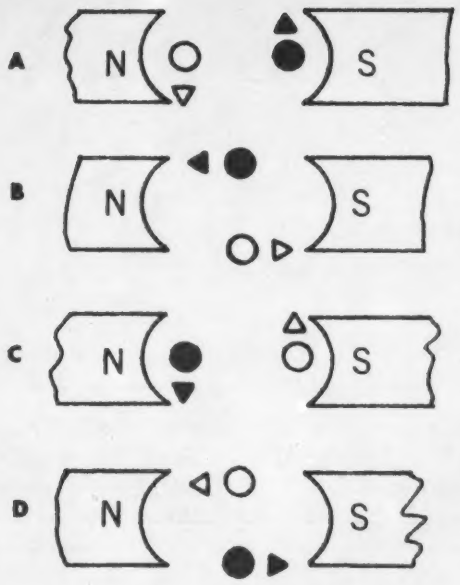
The illustration above shows the two sides of the coil moving parallel to the lines of force.

When the coil is in this position, there is _____ voltage
zero/some
induced in the two sides of the coil because the sides _____
are/are not
cutting lines of force.

- -

(zero - are not)

22.



The figure above shows four positions of the coil.

___ 1. In which position or positions is there no induced voltage?

___ 2. The polarity of the white side of the coil at the end nearest you in A is positive with respect to the opposite end. What is its polarity with respect to the opposite end in C.

___ 3. What is the polarity of the black side of the coil at the end nearest you with respect to the opposite end in C?

___ 4. The coil makes one complete rotation. How many times does the induced voltage change polarity?

- -

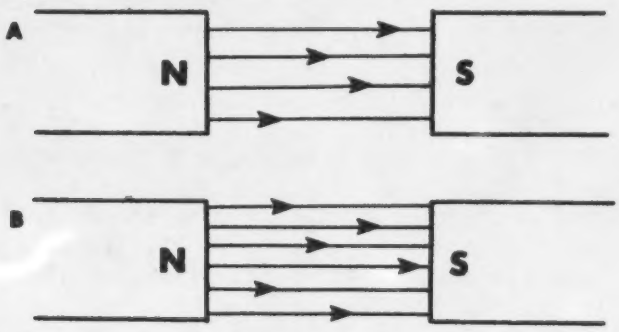
(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 22

1. B and D
2. negative
3. positive
4. 2 times

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 26. OTHERWISE, GO BACK TO FRAME 18 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 22 AGAIN.

23.



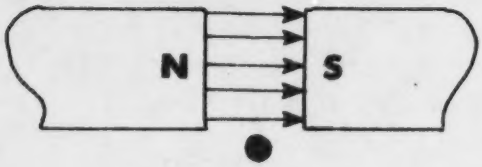
One factor affecting the magnitude of EMF produced is the strength of the magnetic field. Since a flux line reacting with an electron causes the electron to be displaced, it stands to reason that more flux lines cutting a conductor will displace more electrons and produce a higher EMF.

The above illustrations show the relative strength of two magnets. Which illustration will produce the greater amount of EMF? ____

(B)

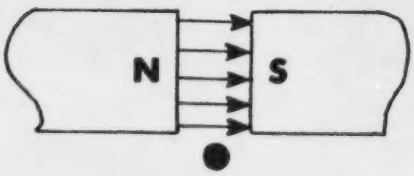
24. Another factor affecting EMF is the speed of relative motion between the flux lines and conductor. The faster the motion, the greater the number of flux lines cut per unit of time, and the greater the EMF produced in that given time.

A



Time required for conductor to move through the field is 5 seconds.

B



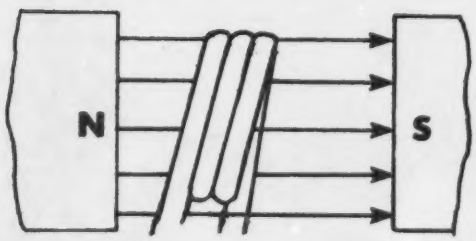
Time required for conductor to move through the field is 1 second.

Study the illustrations above. In which case (A or B) will the EMF produced be the largest? _____

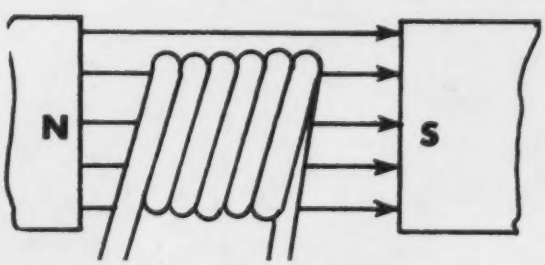
(B)

25. The last factor affecting EMF is the length of the conductor within the magnetic field. Increasing the length of the conductor within the field is done by making the coil out of a piece of wire as illustrated below.

A



B



Which illustration will cause more electrons to be pushed by the lines of force and result in a greater EMF? _____

(B)

26. The three factors that affect the strength of an induced EMF are:

strength of the _____ field, _____ of relative motion, and the length of _____ in the magnetic field.

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 26

Magnetic - speed - wire

- -

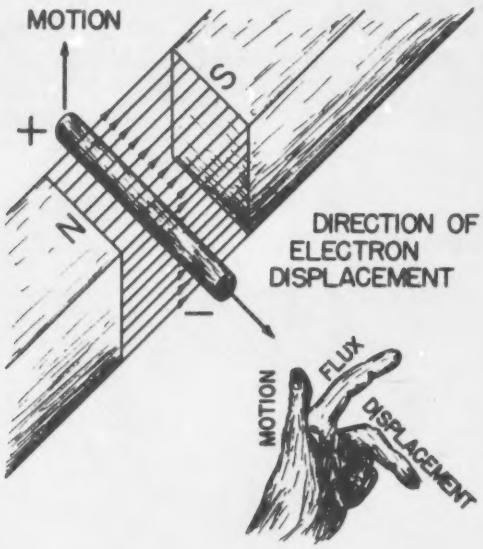
IF ANY OF YOUR ANSWERS ARE INCORRECT, GO BACK TO FRAME 23 AND TAKE THE PROGRAMMED SEQUENCE.

IF YOUR ANSWERS ARE CORRECT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, GO ON TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

SUMMARY
LESSON III

Electromagnetic Induction

Electromagnetic Induction is the action which causes electron displacement in a conductor when lines of force move through it. The lines of force moving with respect to electrons within the wire push the electrons in a direction we can determine by use of the Left-Hand Rule for Generators. To position your hand for this rule hold your left hand in front of you with the thumb pointing up, the forefinger (index finger) pointing to your right, and the middle finger pointing straight toward your chest. The three directions should be at right angles to each other. Keeping your hand in this position, point the thumb in the



direction of the conductor's motion through a magnetic field, the forefinger in the direction of the magnetic flux lines, and your middle finger will indicate the direction of electron movement in the wire. The amount of EMF produced by this electron displacement is determined by three conditions. These are:

1. The strength of the magnetic field. A stronger field produces more EMF.
2. The relative motion between the conductor and the magnetic field. Faster motion generates more EMF.
3. The length of the wire in the magnetic field. More wire being cut by the lines of force will produce a greater EMF.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK, OR YOU MAY STUDY THE LESSON NARRATIVE OR THE PROGRAMMED INSTRUCTION OR BOTH. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANOTHER METHOD OF INSTRUCTION UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM

M O D U L E T W O

L E S S O N I V

Generating AC Voltage

Study Booklet

OVERVIEW
LESSON IV

Generating AC Voltage

In this lesson you will study and learn about the following:

- -generation of alternating voltage
- -amount of EMF
- -graphing AC
- -frequency
- -more AC quantities

Each of the above topics will be discussed in the order listed. As you proceed through this lesson, observe and follow directions carefully.

BEFORE YOU START THIS LESSON, PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON IV

Generating AC Voltage

To learn the material in this lesson, you have the option of choosing, according to your experience and your preferences, any or all of the following:

STUDY BOOKLET:

Lesson Narrative
Programmed Instruction
Lesson Summary

ENRICHMENT MATERIALS:

NAVPERS 93400A-1b "Basic Electricity, Alternating Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.: U.S. Government Printing Office, 1965.

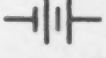
You may study whatever learning materials you feel are necessary to answer the questions in the Lesson Progress Check. All your answers must be correct before you can go to Lesson V. Remember your instructor is available at all times for any assistance you may need.

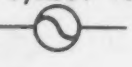
YOU MAY NOW STUDY ANY OR ALL OF THE RESOURCES LISTED ABOVE. YOU MAY TAKE THE PROGRESS CHECK AT ANY TIME.

NARRATIVE
LESSON IV

Generating AC Voltage

As you may already know, there are two different kinds of electricity. The electricity used in your car is not the same as the kind used in your house. The car uses direct current, the house uses alternating current.

Direct current (DC) is the type of electricity we have been discussing so far. DC is the movement of electrons in only one direction through the circuit path. Batteries generate DC from chemical action, and the associated EMF does not change in polarity; also, the value usually is constant. In other words, a DC voltage remains in the same direction and usually in value all the time. Recall the schematic symbol for a DC source is: or 

Alternating current (AC) moves first in one direction, then the other. Magnetic-mechanical generators produce AC, and the associated EMF changes in polarity at intervals and changes in value constantly. Stated another way, an AC voltage is always changing in value and periodically changes in polarity. The schematic symbol for an AC source is a sine wave in a circle as shown: 

Generation of an Alternating Voltage

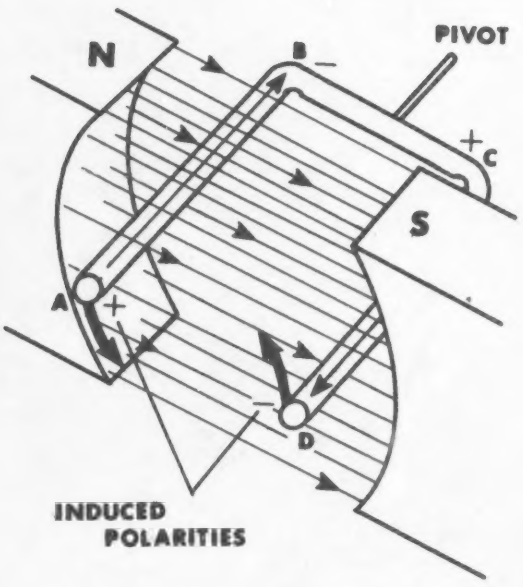
You will recall that when an EMF is generated by electro-magnetic induction, three directional quantities are present:

1. Lines of force, directed from the N pole to the S pole.
2. Motion of the wire with respect to the magnetic field (relative motion).
3. Movement of the electrons within the wire.

The left-hand rule for generators indicates the directions of these values. Applying this rule to a straight wire moving in a magnetic field is a simple task, but most generators use coils or loops of wire, and the rule is slightly more difficult to apply. The following drawing shows this more clearly.

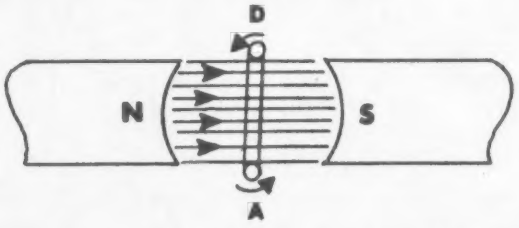
In this drawing, the loop of wire is rotating so that the part of the wire between A and B is moving downward through the magnetic field near the N pole of the magnet. Applying the left-hand rule to this part of the loop shows that electrons are moved from A toward B as shown by the arrow. This means the EMF must be positive (+) at A and negative (-) at B.

(See drawing next page)



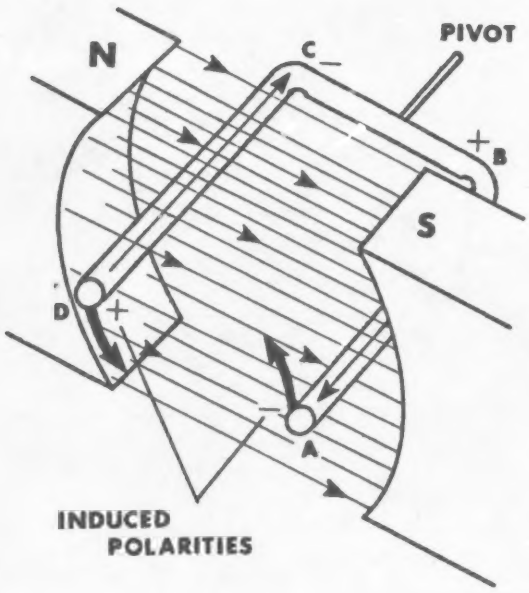
The section of the wire between C and D is, at this same time, moving upward through the magnetic field by the S pole. The left-hand rule used here shows that the electrons are pushed from C toward D, in the opposite direction to the current flow in section AB of the loop. The EMF induced here is positive (+) at C and negative (-) at D. both induced voltages tend to move electrons around the loop in the same way.

As the loop continues to rotate in the magnetic field, it will reach a point where the wires do not cut through the flux lines, and no EMF will be induced in the coil.



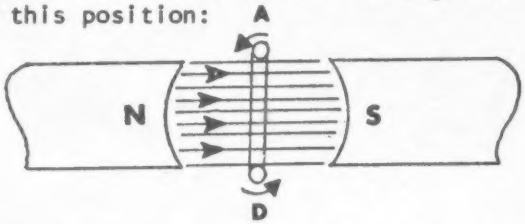
This is because the wires are moving parallel to the lines of force at this instant and are not cutting through them.

As the loop rotates farther, the electrons start to move again. Checking their direction of motion with the left-hand rule shows that they are now moving from D to C and from B to A, directly opposite to their earlier direction in the wire. One-half turn after our starting points, the loop will be in this position:



A is now the negative end of the loop and D the positive end, the exact opposite of the first situation. This reversal of polarity is the difference between AC and DC.

As the loop continues to rotate, it cuts through flux lines until it reaches this position:



Here the motion of the wire is again parallel to the direction of the flux lines and no EMF is generated.

As the loop keeps turning, it will return to its starting position and repeat this cycle of operation so long as some mechanical force keeps it moving.

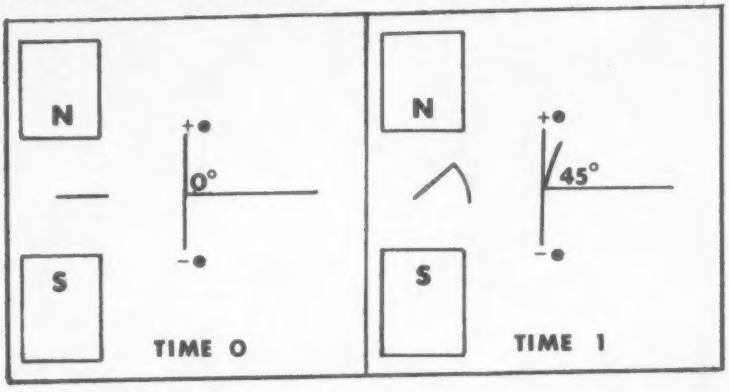
Amount of EMF

You have seen that the generated EMF is zero at two points during each full revolution of the loop, and that EMF is generated first in one direction then in the other as the loop makes a complete turn. This EMF will be maximum at the two points where the wire loop is cutting through the flux lines at a right angle. This is because the wire will cut more lines in a given instant here

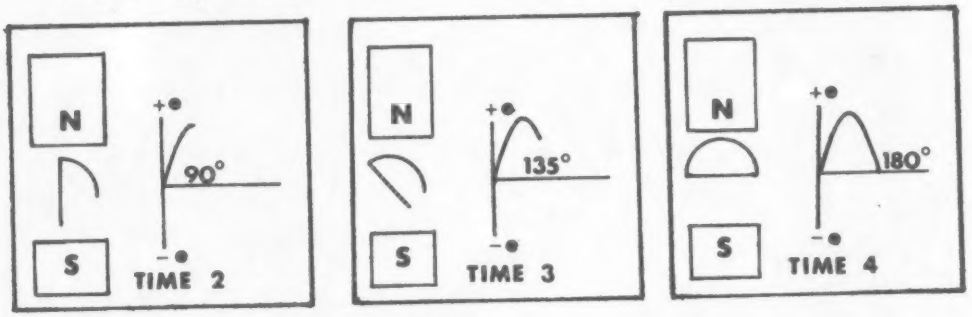
than in any other position. The EMF then varies gradually from zero volts to maximum voltage twice in each revolution, once in one direction, once in the other.

Graphing AC

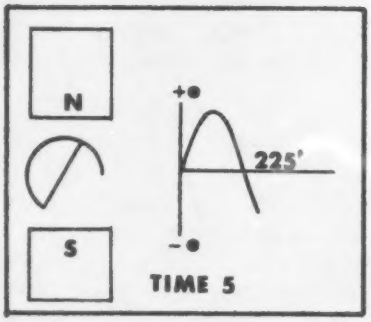
One way to see how much EMF is generated at each moment is to graph the voltage produced by the generator against time. This graph has the shape of a sine wave. In the first block, the loop is shown in the zero voltage position. The time is also shown as zero. In the second block, the loop has turned 45° and the voltage has increased as shown on the graph for Time 1. This time line shows that time has elapsed as the loop has turned.



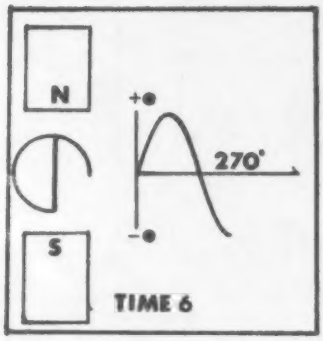
Times 2, 3, and 4 show the voltage output at 90°, 135° and 180° of revolution. With each successive graph, more time has elapsed as the loop turned.

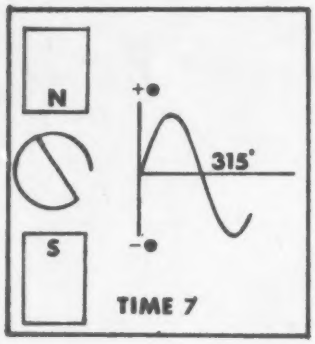


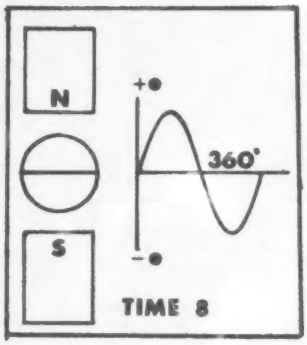
At 180° the wires of the loop are again moving parallel to the lines of force, and no EMF is generated. Further rotation of the loop causes electron motion to commence once more, but now the electrons move through the wire in the opposite direction, as indicated on the graph by the plot of voltage appearing in the negative portion of the graph. The block for Time 5 shows the result of 225° of rotation, with more time lapsing.



In the three final blocks of our graph, the coil rotates back to its beginning position and is now ready to repeat the cycle.







AC Quantities

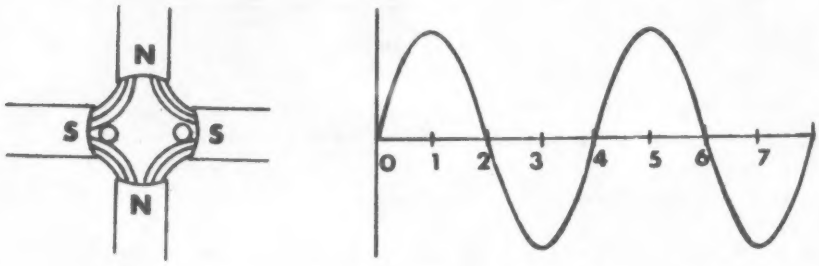
There are several names you need to know and use so that you'll be able to talk with others in your rating about AC. Cycle is one of these words. One cycle of the sine wave represents a complete rotation of the loop in the magnetic field as shown by the graph at Time 8.

Frequency

The frequency (f) of AC is the number of cycles per second, that is, how many times each second the electrons complete their pattern of flow, in first one direction, then the other. Cycles per second is usually called Hertz, abbreviated Hz.

At the two zero points in a cycle, no EMF is being generated, and no current can flow. Since the lights in the room you are in operate from an AC supply, they actually flicker on and off twice during each cycle of the generator. The AC supplied is 60 Hertz and the flicker is so fast (120 times per second) that your eyes cannot detect it.

The frequency of the voltage from a generator depends upon the speed of rotation of the loop. The faster the loop revolves, the more cycles each second, and the higher the frequency. A higher frequency can also be attained if additional pairs of magnetic poles are added to the generator. The following drawing is of a four-pole generator with a graph showing its output. Only one side of the rotating loop is shown.



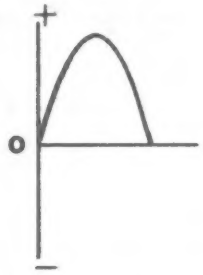
In rotating from position, or time, zero through one complete mechanical revolution, the generator has produced two complete cycles.

To sum up, frequency is affected by two factors:

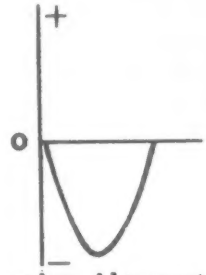
1. the speed of rotation of the wire coil.
2. the number of pairs of magnetic poles.

More AC Quantities

Another word you will need to know is alternation. An alternation is either the positive or negative half of a cycle.



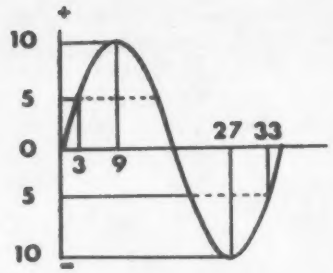
Positive Alternation



Negative Alternation

Amplitude

This is another term you will often hear. This is the number of volts (or amps) at a given time. This is probably easiest to see on a graph. The amplitude of the graph is the distance from the zero line to the sine wave at any point; for example, in the illustration on the next page, the amplitude of this sine wave at time zero is zero; at time 3 msec, it is 5, and at time 27 msec, it is negative 10.

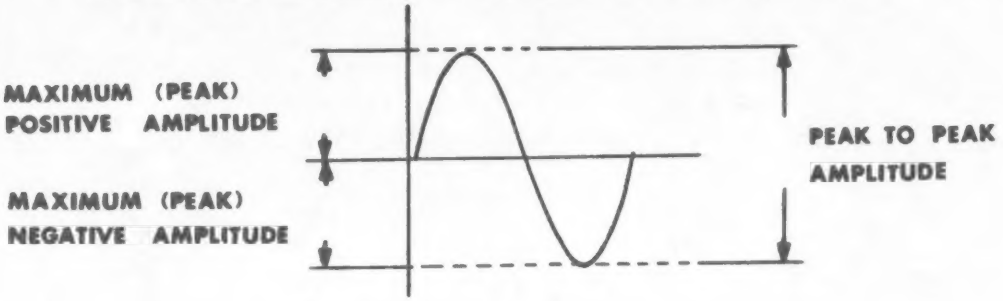


What is the amplitude of the sine wave at time 9 msec? At time 33 msec?

ANSWER: 10; -5

The value of voltage (or current) found at any given instant of time in a sine wave is known as the instantaneous value of voltage (or current), and is symbolized by the lower case letters e for voltage and i for current.

Some points of particular importance on the sine wave are the maximum (peak) amplitude (either positive or negative) and the peak-to-peak amplitude. These are shown on the sine wave below.



Although you will often need to know the maximum of peak-to-peak values for AC, the value most often given is the effective (or RMS) value. This value is used because it is directly comparable to DC values. Ten volts of DC will do exactly the same amount of work as 10 volts of effective AC. The effective value is less than either the maximum or peak-to-peak values, as it is an average of the work done throughout a cycle. If we were to determine the work done over one alternation and average it, we could find the effective value of that alternation, and because each alternation has the same shape, this is the effective value of the sine wave.

Nearly all AC meters are calibrated in effective values so that the values used in AC will be consistent with the values in DC circuits.

AT THIS POINT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON IV

Generating AC Voltage

TEST FRAMES ARE 8, 33, 63 and 92. AS BEFORE, GO FIRST TO TEST FRAME 8 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. Recall that direct current (DC) usually flows at a (constant/variable) rate and always in only _____ direction.

(constant; one)

2. DC is produced by a cell through _____ action.

(chemical)

3. Since DC is known as direct current, you may infer that current which alternates in its flow would be called _____ current.

(alternating)

4. Alternating current (AC) is current which periodically changes its direction of flow.

   The alternating in alternating current comes from the fact that AC _____ _____ _____ of flow.

(periodically reverses direction)

5. As the AC reverses direction it must go through a maximum value of voltage to zero to maximum and back to zero.

   The magnitude of voltage is:

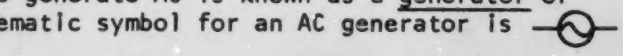
   ___ a. constant.
   ___ b. fluctuating.
   ___ c. direct.
   ___ d. alternating.
   ___

(b. fluctuating and d. alternating)

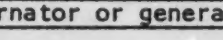
6. AC is commonly produced by converting mechanical energy to electrical energy by electromagnetic induction.

State the method used to produce AC. _____

(Electromagnetic induction.)

7. The component used to generate AC is known as a generator or alternator. The schematic symbol for an AC generator is 

Mechanical energy is converted to electrical energy by electromagnetic induction in a/an _____ represented schematically by _____.

(alternator or generator: )

8. Match the type of current to the appropriate descriptive phrases.

___ 1.	electrons moving in only one direction	a. Direct Current
___ 2.	electrons always moving at a fluctuating rate	
___ 3.	electrons usually moving at a constant rate	b. Alternating Current
___ 4.	can be generated by chemical action	
___ 5.	generated by magnetic-mechanical action	
___ 6.	electrons reversing direction	

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 8

1-a
2-b
3-a
4-a
5-b
6-b

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO ON TO TEST FRAME 33. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 8 AGAIN.

9. A

B

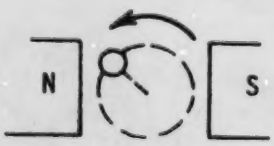
Generators have two major parts:

1. A stator (non-rotating part)
2. A rotor (rotating part)

A basic, single conductor generator looks like illustration A. It can also be represented as in illustration B. The circle at point C represents a _____ rotating in a stationary magnetic field.

(conductor)

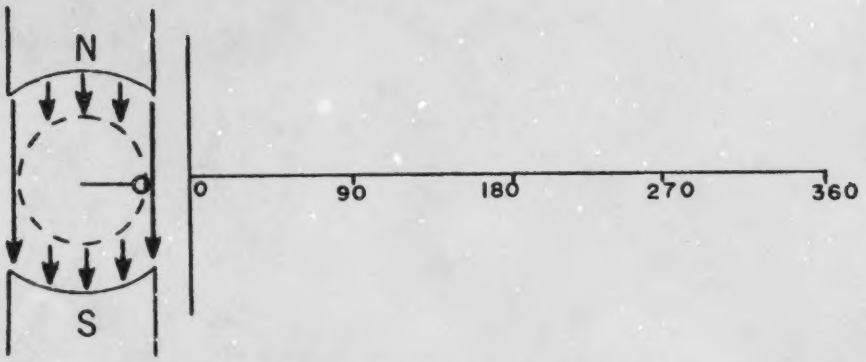
10.



Note the conductor rotation indicated on the above illustration; as determined by the left-hand rule for generators, the direction of conductor current flow is _____ the page.
into/out of

(into)

11.



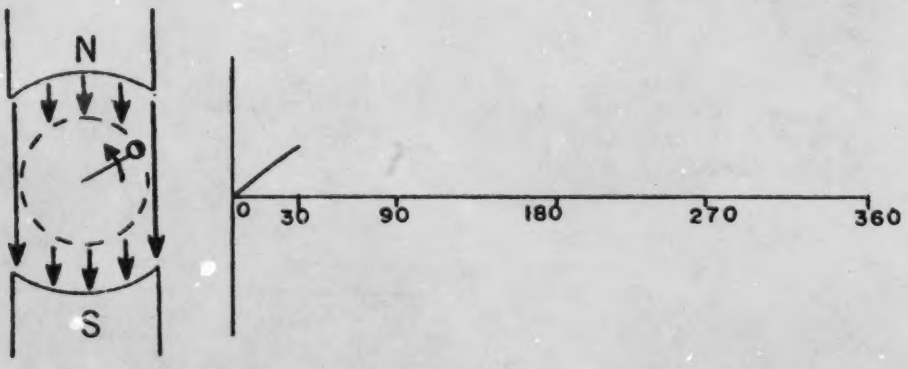
Starting a graph of voltage vs. conductor position at the point shown above is standard practice.

At zero degrees, the path of the conductor is parallel with the lines of force. Lines of force are _____ cut.
being/not being

In the illustration, is there an induced current flowing in the conductor? _____

(not being; No)

12.



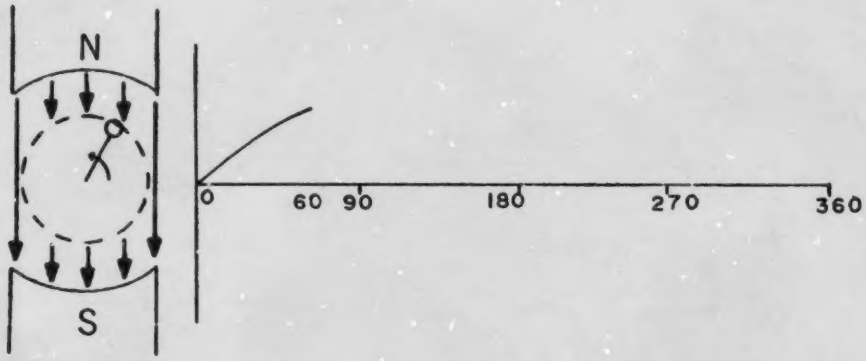
By moving to the 30° position, as indicated in the above figure, the conductor's path has become more nearly _____ to the lines of force.
parallel/perpendicular

(perpendicular)

13. In frame 12, lines of force _____ being cut
(are/are not)
and an EMF _____ being generated.
(is/is not)

(are; is)

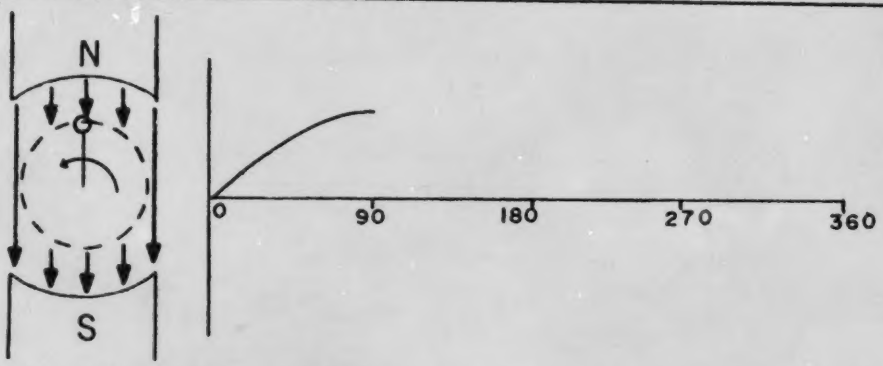
14.



1. At the 60° position, the _____ path has become nearly perpendicular to the lines of force.
2. From the 30° to the 60° position, the induced EMF has _____.
(increased/decreased/remained the same)

(1. conductor; 2. increased)

15.



At the 90° position, the conductor is traveling perpendicular to the lines of force, and the induced EMF is _____.
(the same/minimum/maximum)

(maximum)

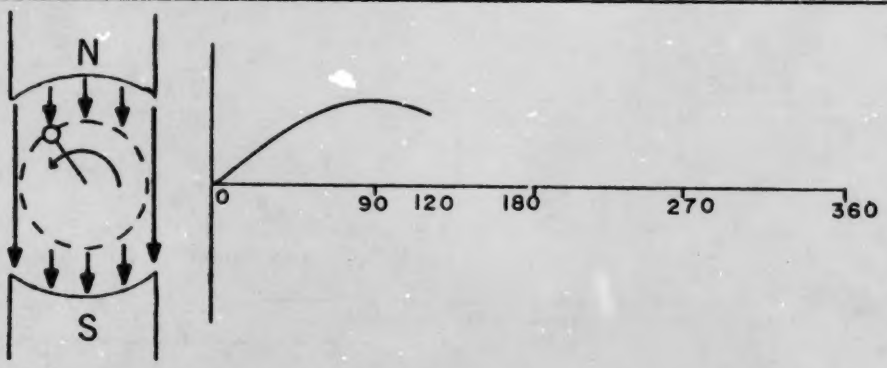
16. In frame 15, at the 90° position, the current in the conductor is flowing _____ the page.
into/out of

(into)

17. Maximum lines of force are being cut at the _____ degree position of the conductor.

(90°)

18.



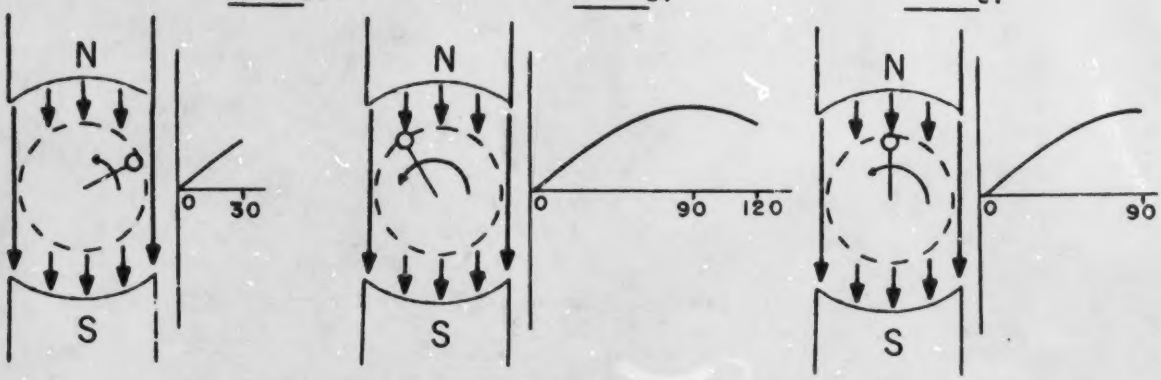
Moving to the 120° position, the conductor is at the same relative cutting angle as at the 60° position. Induced EMF at the 120° position compared to that at the 90° position has _____.
increased/decreased/remained the same

(decreased)

19. In the above figure, at the 120° position the conductor is cutting fewer lines of force than at 90° because it is more nearly _____ to the magnetic flux.
perpendicular/parallel

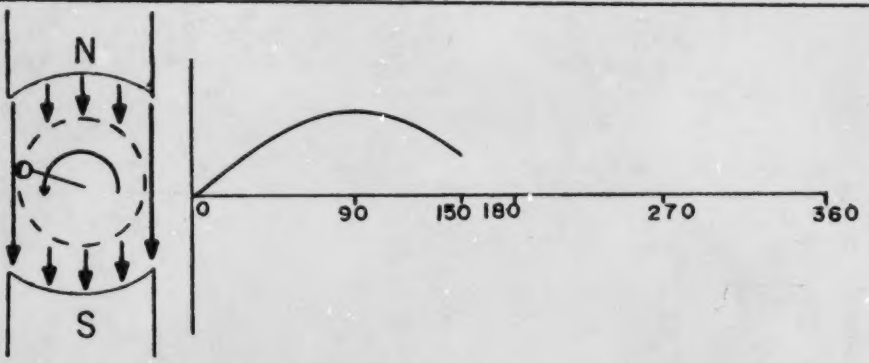
(parallel)

20. In which drawing would the greatest amount of EMF be generated?



(c)

21.



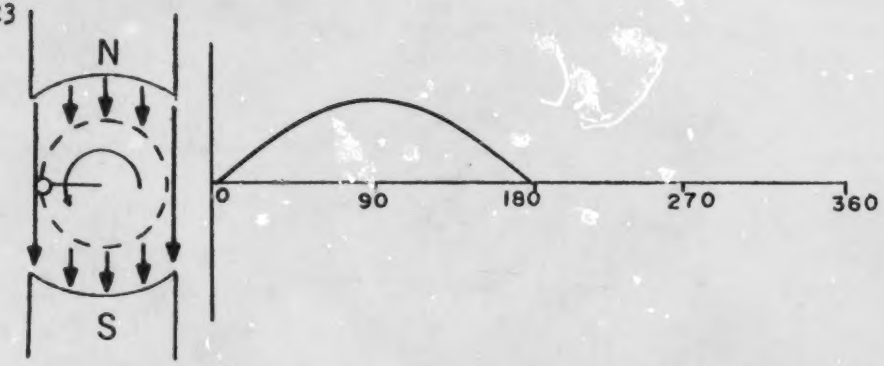
Continuing to move the conductor in the same direction to the 150° position, we find that _____ lines of force are being cut.
more/less/the same

(less)

22. Refer to above drawing. At the 150° position we find that the induced EMF has _____.
increased/decreased/remained the same

(decreased)

23



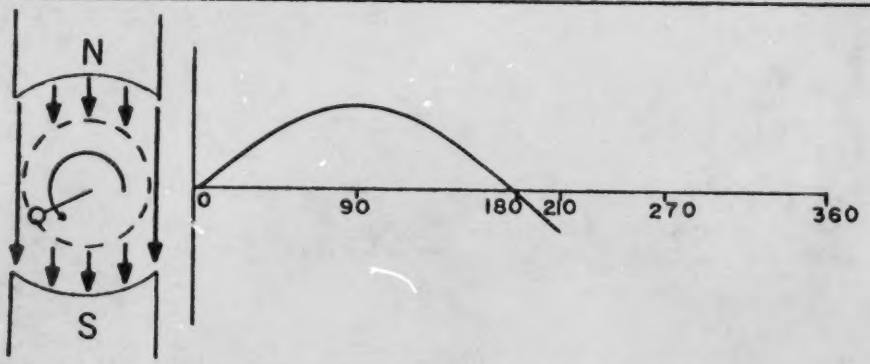
Now, let us move the conductor another 30° to the 180° position. The induced EMF at the 180° position is _____.

(zero)

24. Refer to the above drawing. During the first 180° of rotation, maximum induced EMF was generated at the _____ degree position.

(90)

25.



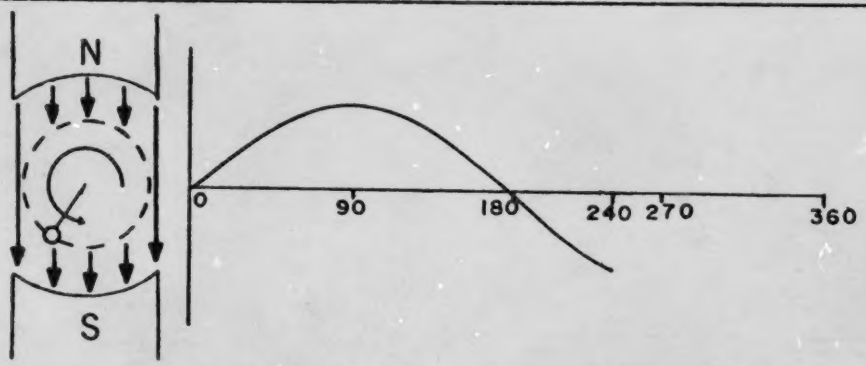
Move the conductor another 30° to the 210° position as indicated. Again the conductor is starting to cut some lines of force. Induced EMF is _____ (increasing/decreasing) in the _____ (same/opposite) polarity.

(increasing - opposite)

26. With the relative position of the conductor at 210°, as indicated in the above figure, the current flow in the conductor is _____ the page.
into/out of

(out of)

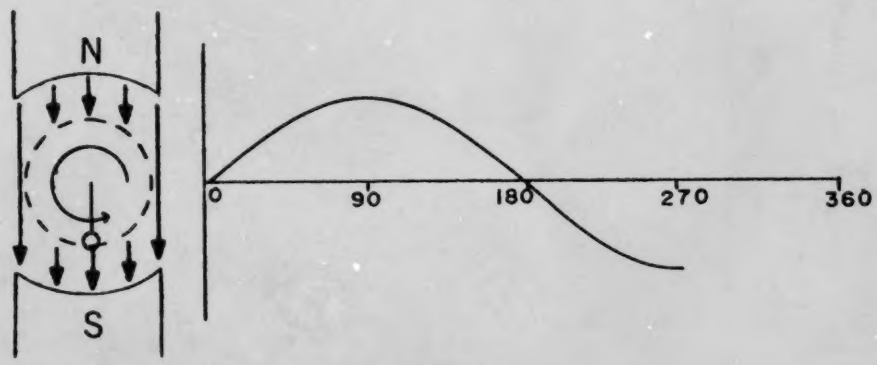
27.



Continuing the movement of the conductor through the magnetic field to the 240° position, we find that _____ magnetic lines of force are being cut.
more/less/same

(more)

28.



Moving the conductor another 30° to the 270° position, induced EMF becomes equal but opposite in polarity to the EMF generated at the _____ degree position.

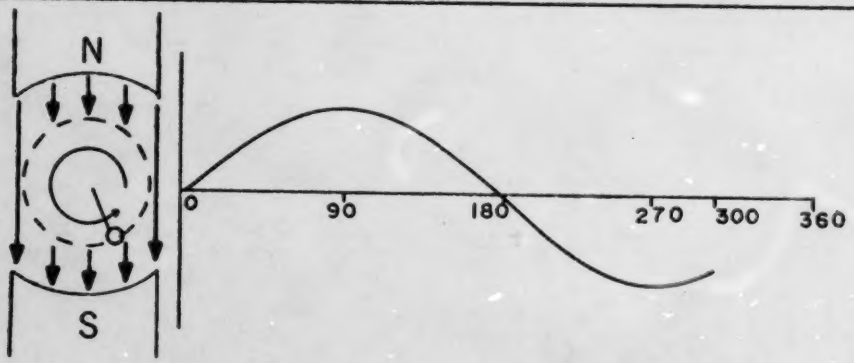
---

(90)

29. During the second alternation, maximum induced EMF was achieved at the _____ degree position.

(270)

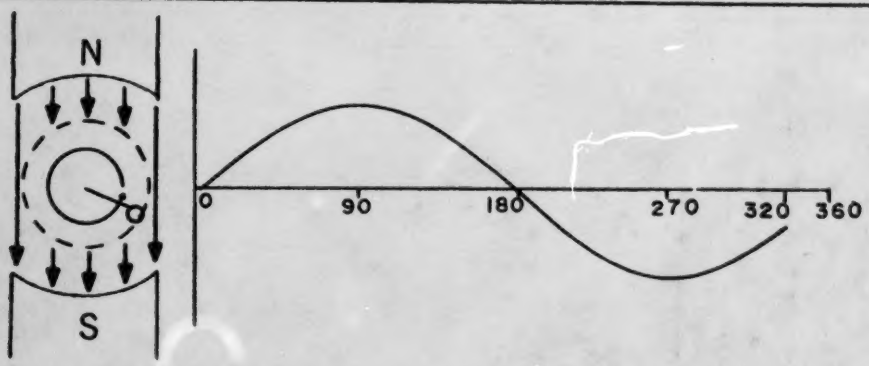
30.



During the rotation from the 270° to the 300° position, the induced EMF has _____.
increased/decreased/remained the same

(decreased)

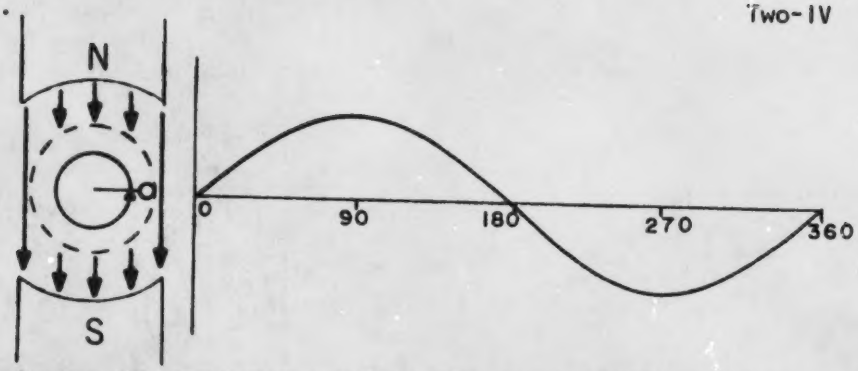
31.



With movement of the conductor to the 330° position, induced EMF will decrease, because _____ lines of force are being cut.

(fewer)

32.

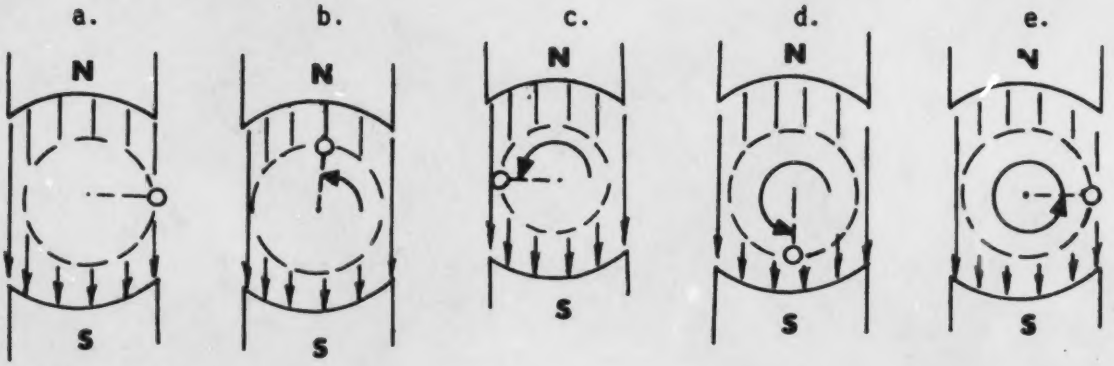


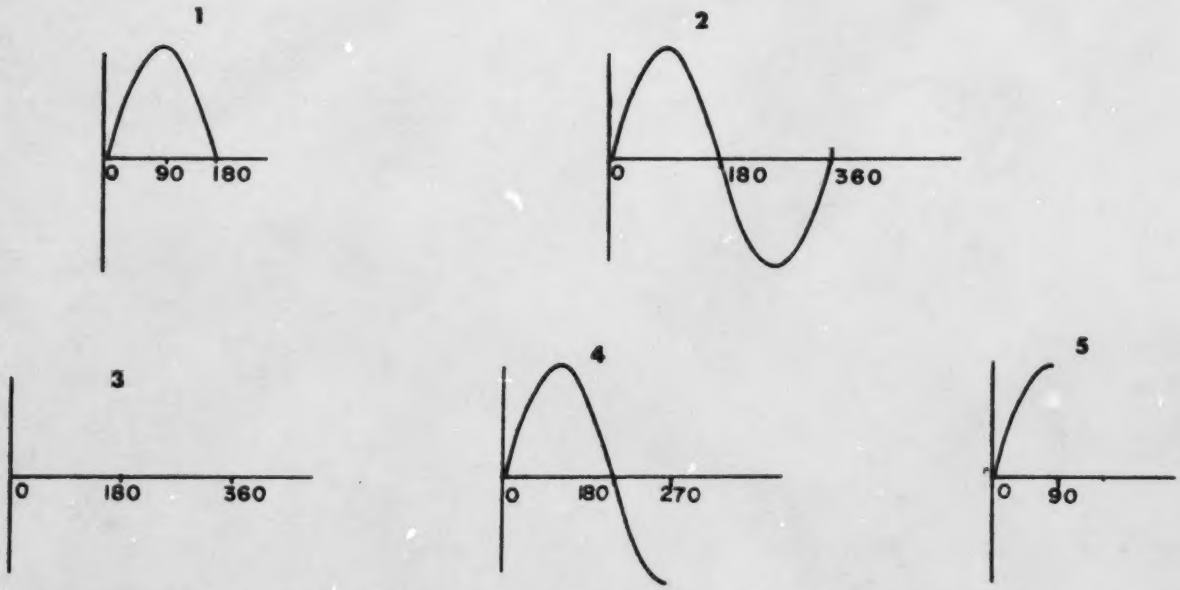
Moving the conductor another 30°, to the 360° position, we have completed one cycle. List the position(s) in one cycle where maximum induced EMF is generated.

a. _____
b. _____

(a. 90°; b. 270°)

33. Match the sine graphs with the appropriate loop positions.





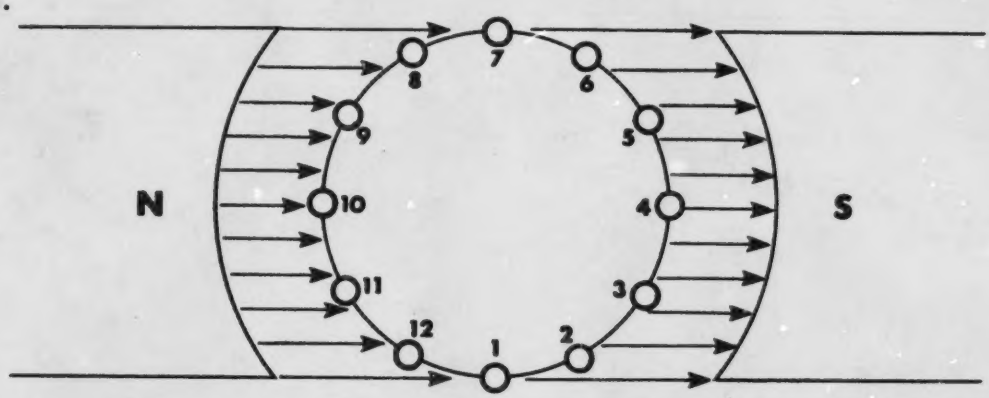
(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 33

1. c
2. e
3. a
4. d
5. b

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, GO ON TO TEST FRAME 63. OTHERWISE, GO BACK TO FRAME 9 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 33 AGAIN.

34.



On the above figure, label the position(s) where maximum induced EMF is achieved by placing an X upon your selection.

(4 and 10)

35. Up to this point in the program, we have used a single conductor to demonstrate the development of induced EMF. However, a single conductor that moves through a magnetic field is not practical for producing a usable voltage, because the induced voltage is too _____.
low/high

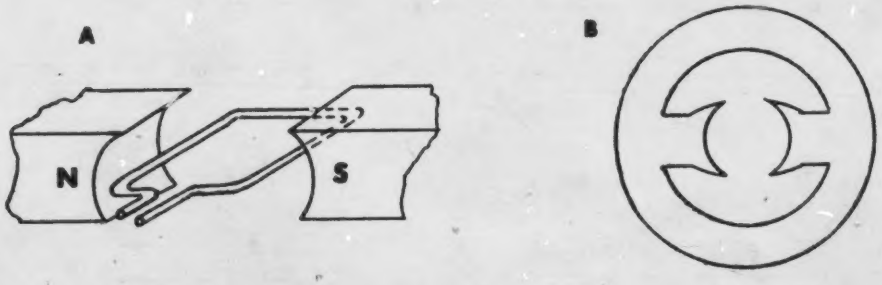
(low)

36.

The action of a conductor cutting a magnetic field forms the basis of GENERATOR operation. For example, here's a simple AC generator consisting of a permanent magnet and a coil of wire. When the coil _____ the magnetic field, a _____ is induced in the coil.

(cuts; voltage)

37.

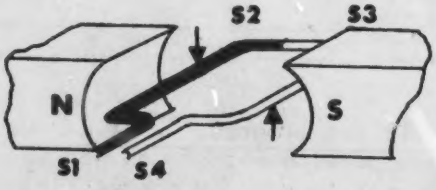


Part A shows just the ends of the permanent magnet. Actually, the magnet is continuous, as in part B.

The permanent magnet provides the _____ _____ in which the coil rotates.

(magnetic field)

38.



The black side of the coil is moving down through the magnetic field. The polarity of S1 with respect to S2 is positive. What is the polarity of S2 with respect to S1? _____. Current flows from the white side of the coil, out of S4 through a load and back in S1.

(negative)

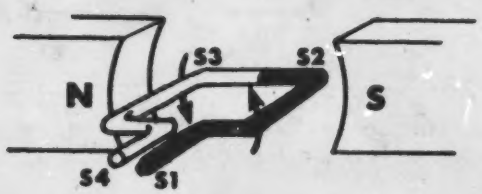
39.

When the coil is in the position shown, the sides of the coil are moving _____ to the lines of force.
parallel/at right angles

Therefore, _____ voltage is induced in the coil.
some/zero

(parallel, zero)

40.



The black side of the coil is moving up through the magnetic field. Current flows from the black side of the loop, out of S _____ through the load to the white side of the loop.

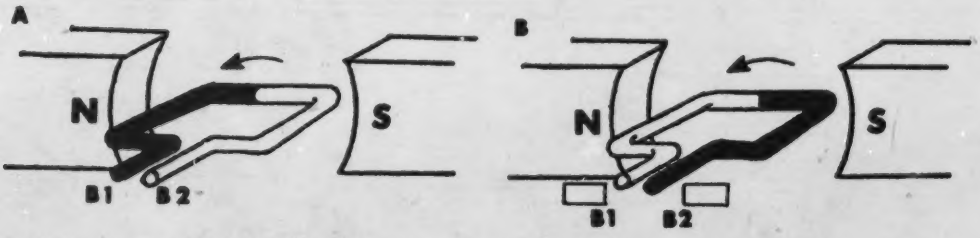
(S1)

41.

When the coil is in the position shown, there is no current flow through the load because the sides of the coil are moving _____ to the lines of force. Therefore, _____ voltage is induced in the coil.

(parallel - no)

42.



Part A shows the black side of the coil moving down. Current flows from B2, through a load, to B1. Part B shows the black side moving up. Write the correct polarities in the boxes next to B1 and B2.

(B1 + and B2 -)

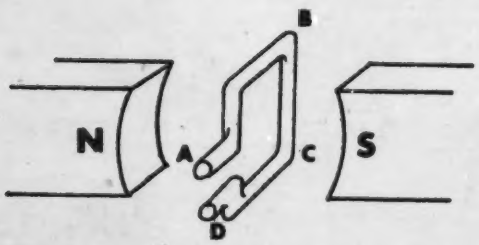
43. What would happen to the polarity if the direction of the coil rotation were reversed? _____

(polarity would reverse)

44. On each illustration indicate polarity between the points listed. (+, -, no polarity)

1. A is ___ with respect to B.
   B is ___ with respect to A
   C is ___ with respect to D
   D is ___ with respect to C

2. A is ___ with respect to B
   B is ___ with respect to A
   C is ___ with respect to D
   D is ___ with respect to A



3. A is ___ with respect to B
   B is ___ with respect to A
   C is ___ with respect to D
   D is ___ with respect to A

(1. a +
b -
c +
d -

2. a -
b +
c -
d +

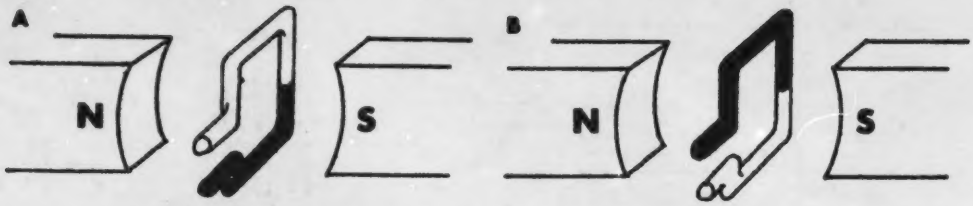
3. a No P
b No P
c No P
d No P)

45.

In part A the black side of the coil is moving down. In B, it is moving up through the magnetic field. Current flow through the coil is in the _____ direction in A and B.
same/opposite

(opposite)

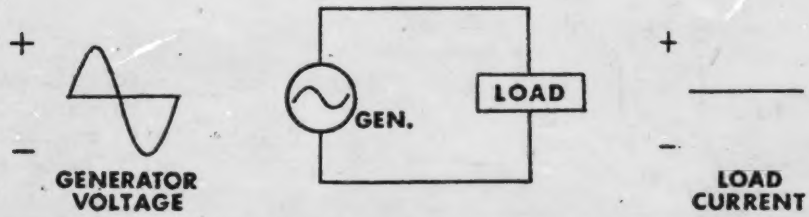
46.

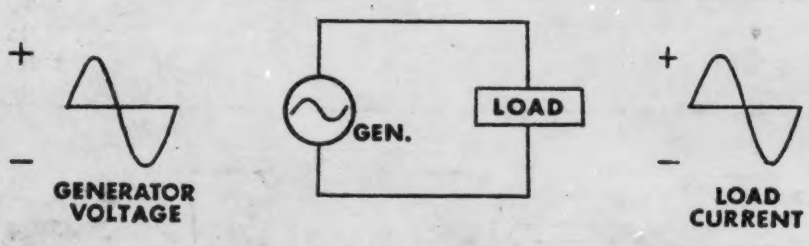


In parts A and B, the sides of the coil are moving parallel to the magnetic field. Is a voltage being induced? _____
Why? _____

(No. The conductor is not passing through the lines of force.)

47. The circuit below shows an alternating voltage from an AC generator applied across an external circuit (marked load). The current through the load follows the same shape as the alternating voltage sine wave. Draw the sine wave for the current through the load in the space provided.



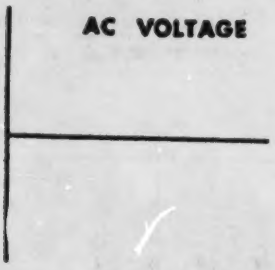


48. Because the amplitude of the current varies continuously and reverses direction just like the alternating voltage, the current that flows in a circuit as a result of an alternating voltage is called _____ current.

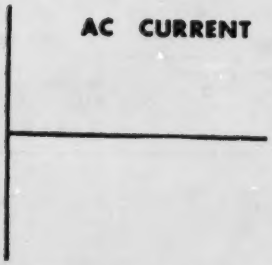
(alternating)

49. Draw a sine wave of alternating voltage in A below. In part B, draw a sine wave of alternating current. Include polarities in your drawings.

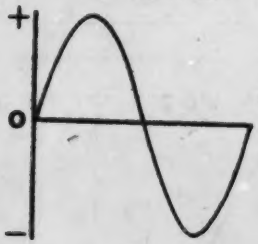
a AC VOLTAGE



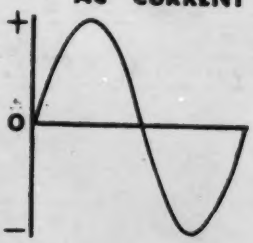
b AC CURRENT



a AC VOLTAGE



b AC CURRENT



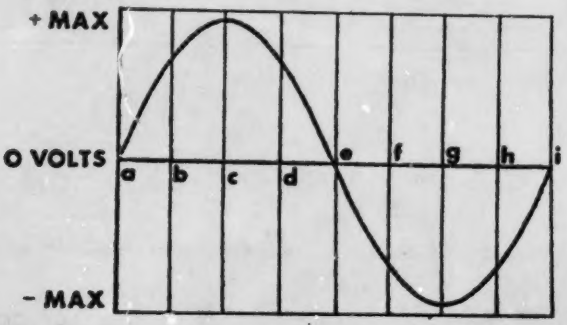
50. When a coil rotates in a magnetic field, it makes a complete circle called a revolution. A circle consists of 360 degrees. The symbol for degrees is a small circle like this (°). Thus 360 degrees is written as 360°. When a coil makes a complete circle, it has gone through one _____ or _____.

One complete revolution is 360°. How many degrees are in 1/2 revolution? _____

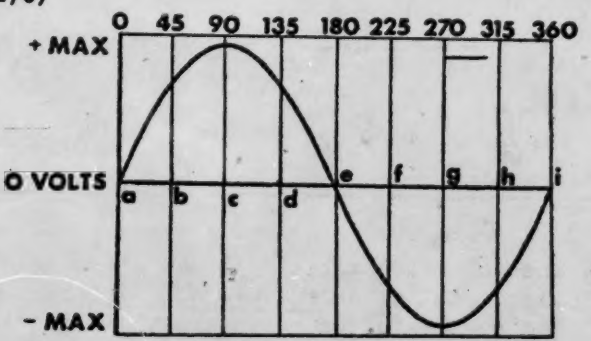
(revolution; 360°; 180°)

51. The figure below shows a sine wave representative of the generator output voltage. Write in the number of degrees the coil has rotated at each position (marked A through I.)

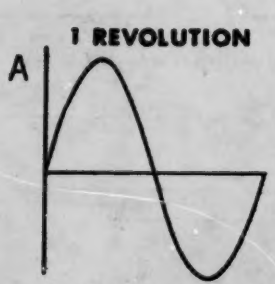
The sine wave represents _____ (how many) revolution(s) of the coil. The voltage reaches the highest positive value at _____ degrees and a negative maximum value at _____ degrees.

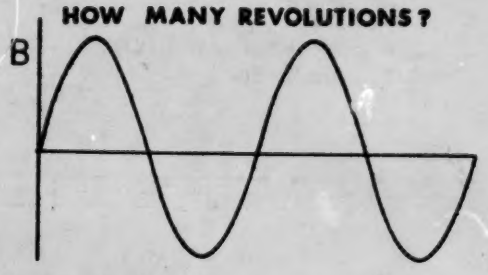


(1 revolution; 90°; 270)



52.

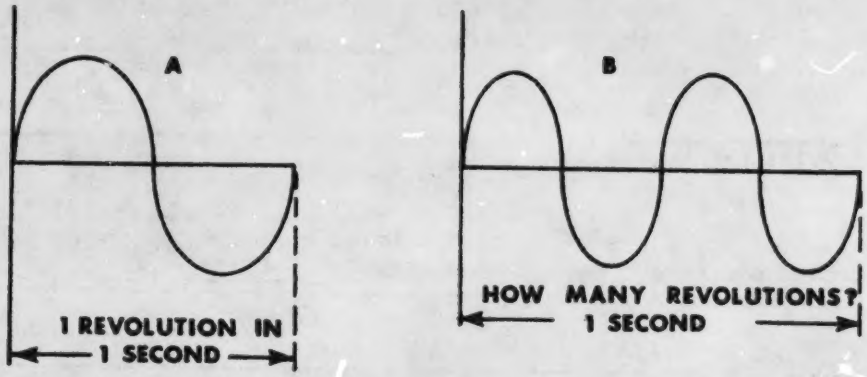




When a coil is rotated in a magnetic field, the voltage induced is represented by a sine wave. The sine wave in Part A represents one revolution of the coil. How many revolutions does the sine wave in Part B represent? _____

(two revolutions)

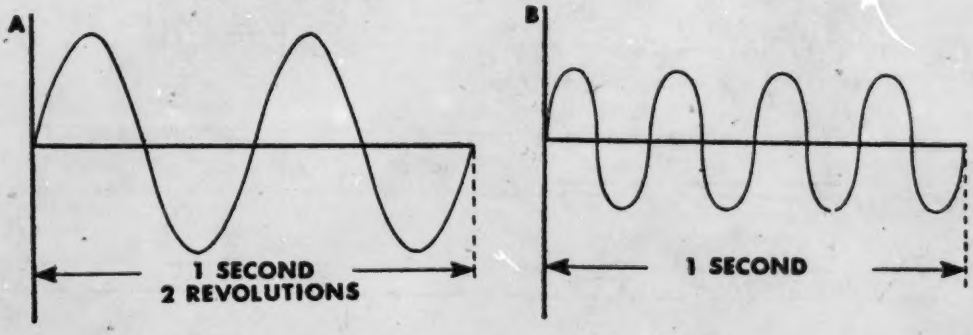
53.



Assume that it takes a coil one second to make a complete revolution. Part A shows the sine wave of voltage generated in one second. How many revolutions per second does the sine wave in Part B represent? _____

(two revolutions per second)

54.



The sine wave in A represents two revolutions of the coil in one second. How many revolutions per second does the sine wave in B represent? _____

(four revolutions per second)

55. Hertz, abbreviated Hz, represents cycle per second. So if a coil makes four revolutions per second, then it has made four _____.

(cycles per second or Hertz)

56. Another way of saying that a coil makes 10 revolutions in one second is that the coil makes 10 _____ per _____.

(cycles per second)

57. If a coil completes five revolutions in one second, how many cycles of voltage has it generated? _____

(five)

58. How many cycles of voltage does a coil generate when it completes 60 revolutions in one second? _____

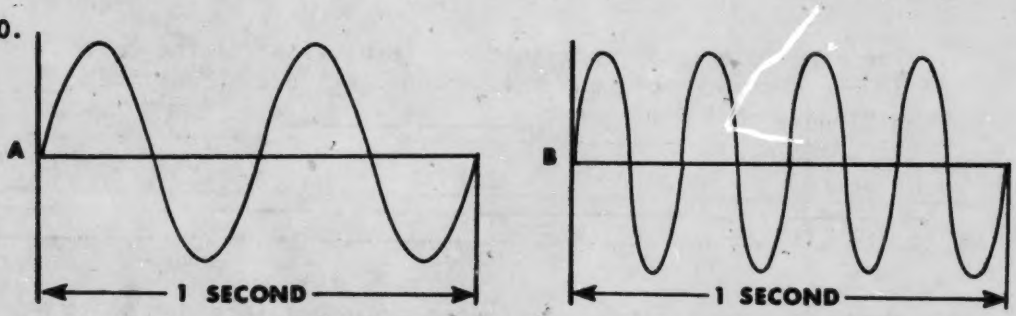
(60)

59. The number of complete cycles generated in one second is called the frequency of the generator. The word frequency is used to tell how frequently the generator produces a voltage cycle. Frequency is abbreviated f.

So if a coil completes 15 revolutions per second, we say its _____ is 15 Hertz.

(frequency)

60.



The frequency of the sine wave in Part A is _____ _____.
What is the frequency of the sine wave in Part B? _____ _____.

(2 Hertz; 4 Hertz)

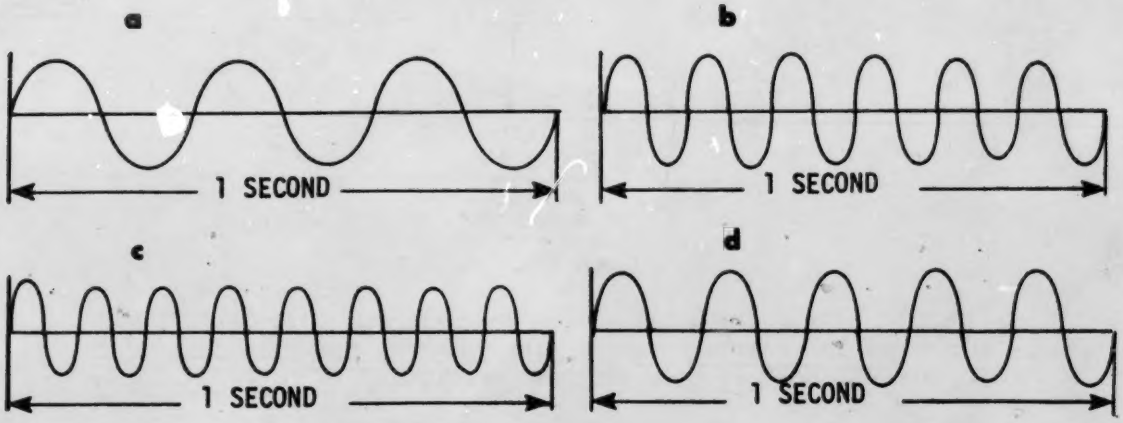
61. A coil completes 30 revolutions in one second. If the speed of the coil is doubled, what is the frequency generated? _____

(60 Hertz)

62. The number of cycles completed in one second is called _____.

(frequency)

63.



Referring to the above figures, what is the frequency in each case?

a. _____
b. _____
c. _____
d. _____

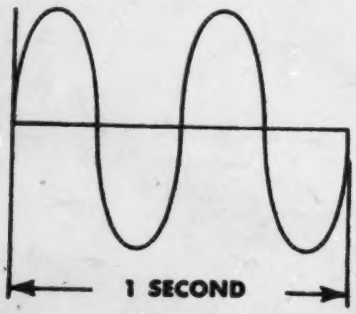
(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 63

a. 3 Hz
b. 6 Hz
c. 8 Hz
d. 5 Hz

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, GO ON TO TEST FRAME 92. OTHERWISE, GO BACK TO FRAME 34 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 63 AGAIN.

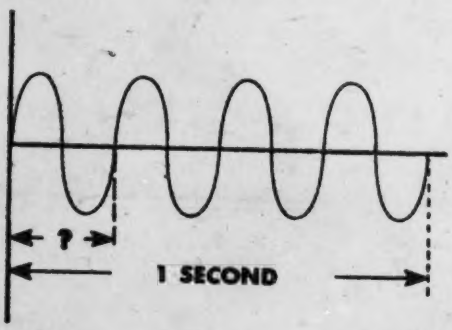
64.



The sine wave above has a frequency of 2 Hz. This means that there are two complete cycles each second. How long does it take the coil to complete just one cycle? _____

(1/2 second)

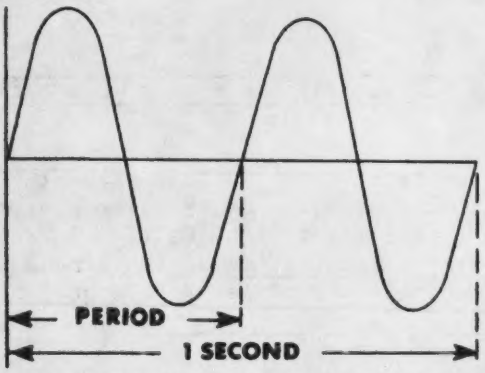
65.



The frequency of the sine wave above is 4 cycles per second. How much time does it take to complete one cycle? _____

(1/4 second)

66. The time the coil takes to complete one cycle is called the <u>period</u>. What is the period of the sine wave shown below?

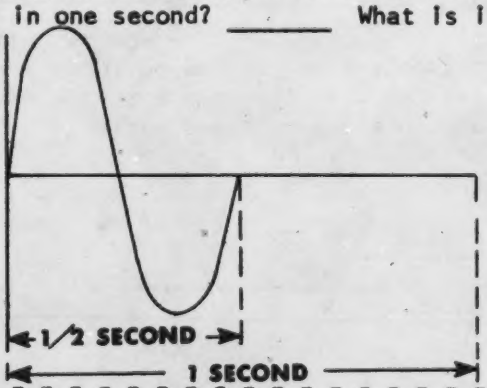


(1/2 second)

67. The frequency of a sine wave is given in <u>Hertz</u>. The time of one cycle is called the _____.

(period)

68. The sine wave below has a period of 1/2 second. How many cycles are there in one second? _____ What is its frequency? _____

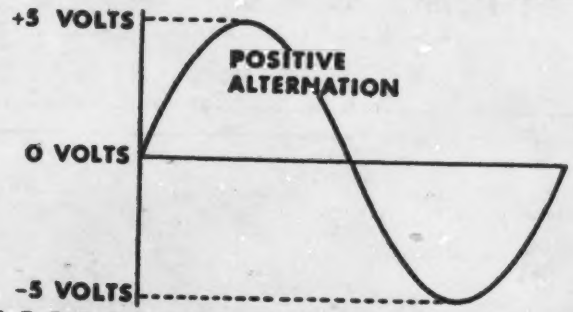


(2; 2Hz)

69. The difference between frequency and period is that frequency means _____ and period means _____ _____.

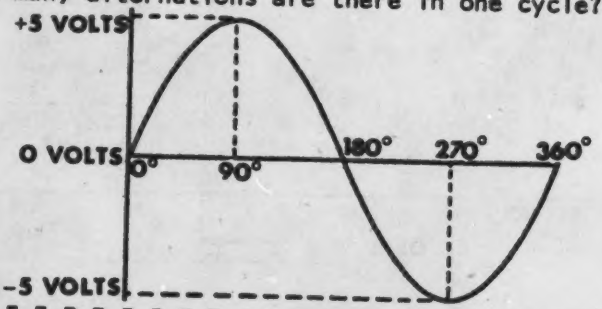
(number of cycles per second; the time of one cycle)

70. The sine wave of voltage below indicates that the voltage rises from 0 volts to a maximum value of +5 volts and then falls to 0 volts again. This rise and fall of voltage in a positive direction is called the positive alternation of the sine wave. By the same token, the rise and fall of voltage in a negative direction is called the _____ _____.



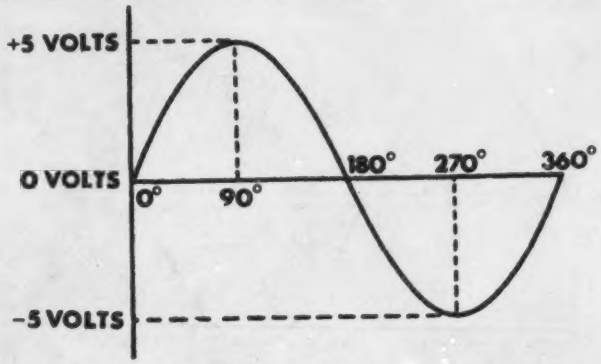
(negative alternation)

71. Here's the sine wave of voltage again. How many degrees of rotation does the coil go through in the positive alternation? ____
How many degrees are there in the negative alternation? ____
How many alternations are there in one cycle? ____



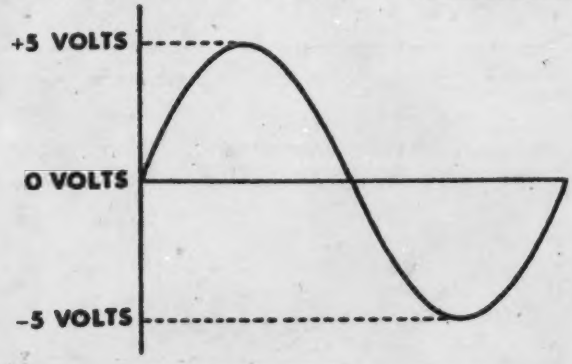
(180°; 180°; 2)

72. Notice below that voltage reaches its maximum positive value at 90°. When does voltage reach its maximum negative value? _____.



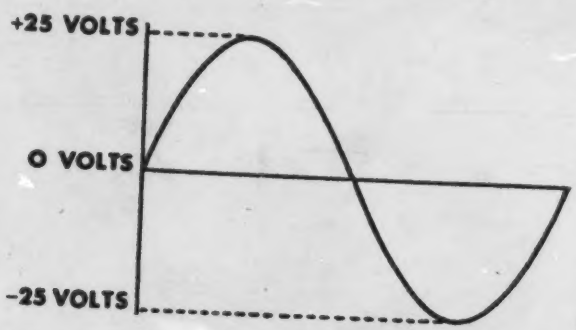
(270°)

73. Peak has the same meaning as maximum. What is the peak voltage reached during the positive alternation of the sine wave below? _____ What is the peak voltage reached during the negative alternation? _____



(+5 volts; -5 volts)

74. The peak voltage of the positive alternation of the sine wave below is _____ volts. What is the peak voltage of the negative alternation? _____

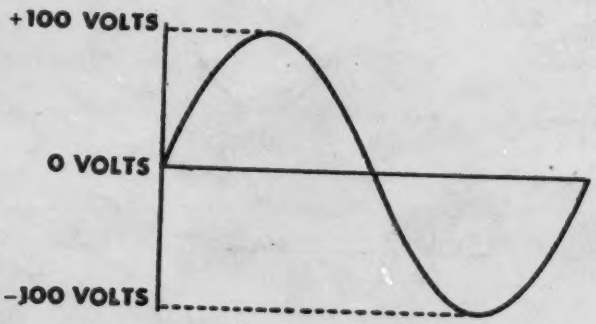


(+25v; -25v)

75. In a sine wave, the positive peak value and the negative peak value are always _____.
alike/different

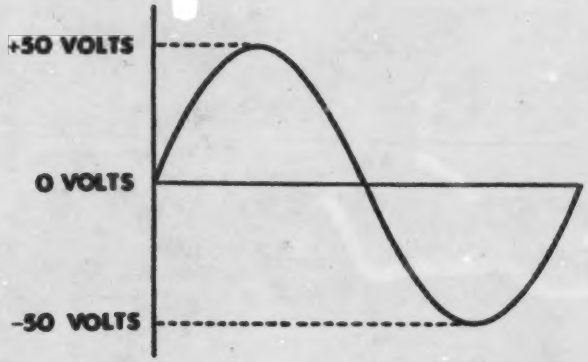
(alike)

76. In the sine wave below, what is the total voltage between the positive peak and the negative peak. (Disregard the polarities.)



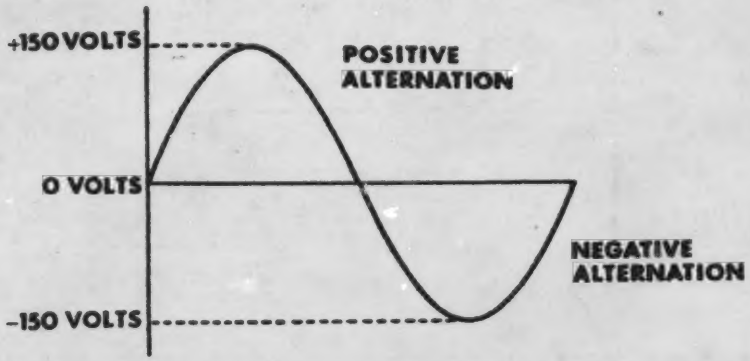
(200 volts)
(From +100 to 0 equals 100 volts and 0 to -100 equals 100 volts. Thus, the total is 200 volts.)

77. What is the total voltage between the positive peak and the negative peak of the sine wave below? _____



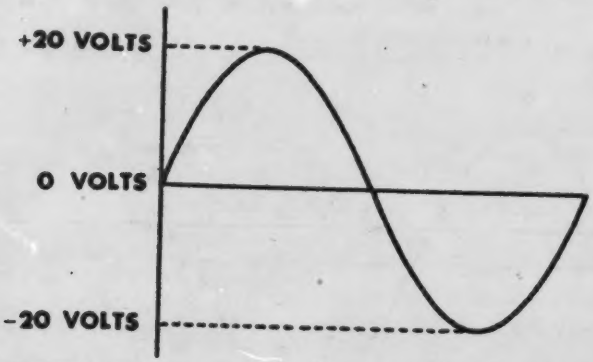
(100 volts)

78. The total voltage between the positive peak and the negative peak is called the peak-to-peak voltage. What is the peak-to-peak voltage of this sine wave? _____



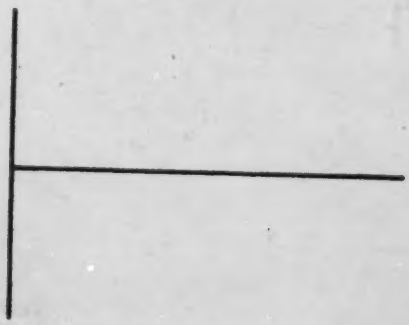
(300 volts)

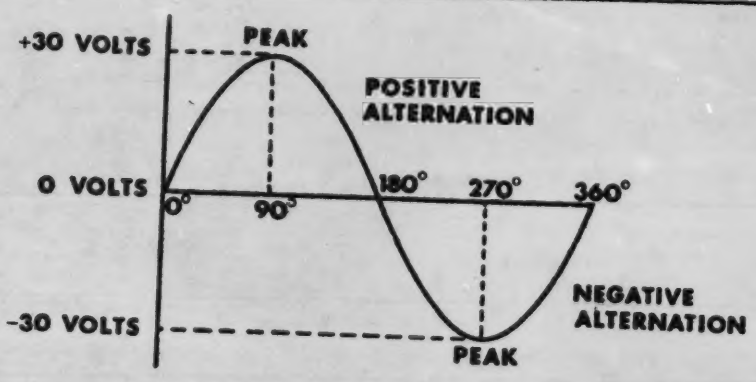
79. The peak-to-peak voltage of this sine wave is _____.



(40 volts)

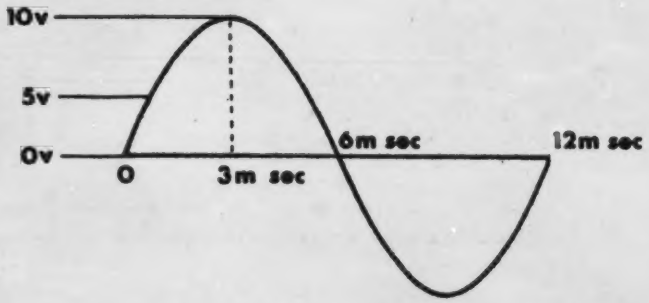
80. Draw a sine wave with a peak-to-peak voltage of 60 volts. Indicate which part of the sine wave is the positive alternation and which part is the negative alternation. Also lable the peak voltage and indicate where it is on the sine wave.





81. Another term you will need to know is instantaneous value. This is the value of voltage or current at any instant of time during a sine wave.

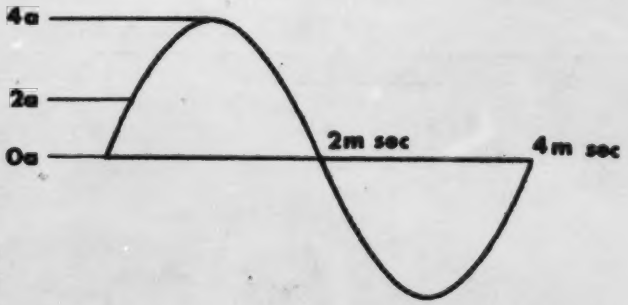
What is the instantaneous value of voltage 3 msec after the start of the sine wave?



___ a. 0 v
___ b. 5 v
___ c. 10 v

(c) 10 v

82. What would be the instantaneous value of current at a time of 4 msec.



___ a. 0 a
___ b. 2 a
___ c. 4 a

(a) 0 a

83. The magnitude of voltage in a sine wave found at any given instant of time is known as the _____ _____.

(instantaneous value)

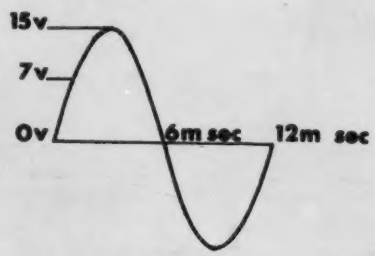
84. Lower case letters are used to symbolize the instantaneous values of current or voltage.

Select the symbols used to indicate the instantaneous values of voltage and current.

____ a. E; e
____ b. I; i
____ c. I; E
____ d. e; i

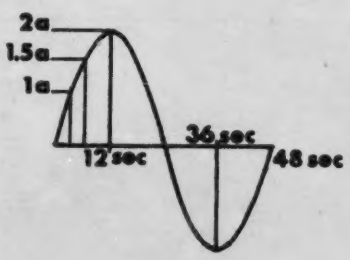
(d) e; i

85. Find e at 9 msec:



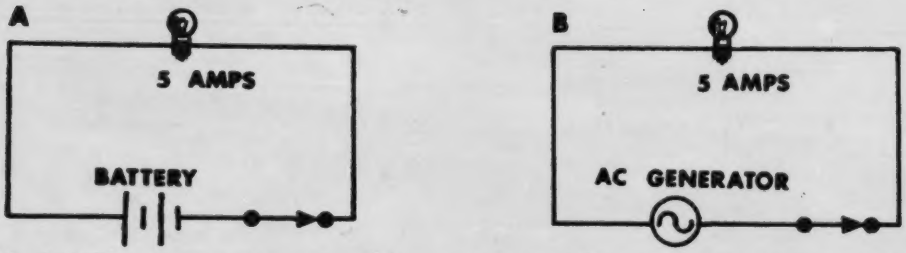
(-15 v)

86. Find i at 6 sec.



(1.5 a)

87. Now you'll apply what you've learned to some practical examples. The lamps in the circuits below require 5 amperes of current to light brightly. Circuit A is a DC circuit in which a constant current of 5 amps flows. Circuit B is an AC circuit in which the peak current is 5 amps. In which circuit does the lamp light brighter? _____ Why? _____



(Circuit A because the 5 amps DC is constant.)

88. To determine the worth or to tell how effective an alternating current or voltage is, we compare the effect of the AC against the effect of DC. Nearly all AC meters are calibrated in effective values so that the values in AC will be consistent with the values in DC circuits. For example, if an alternating current produces as much heat as 1 amp of direct current, then, we say that the AC is as _____ as 1 amp DC.

(effective)

89. The effective value, also called RMS value, of an AC voltage or current has the same heating effect as an equal value of direct current. So if a peak current of 7 amps AC produces the same heating effect as 5 amps DC, then 5 amps is the _____ value of 7 amps AC (peak value).

(effective)

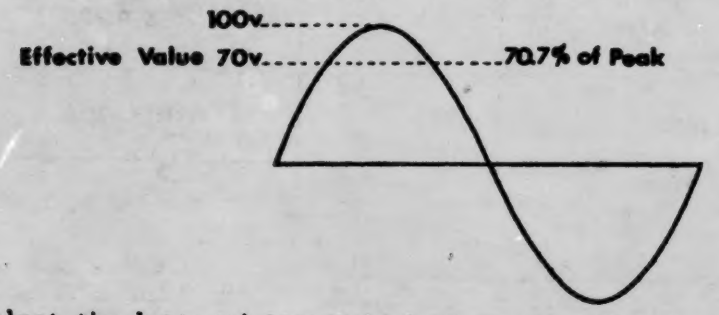
90. A peak AC voltage of 100 volts produces the same heating effect in a load as 70 volts DC. Therefore, the _____ value of the AC voltage is _____ volts.

(effective; 70 volts)

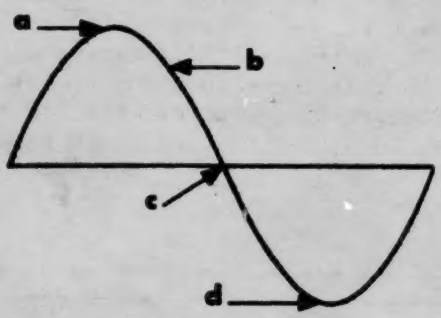
91. For a sine wave, the ROOT MEAN SQUARE (RMS) or EFFECTIVE VALUE is 0.707 times the peak value.

The RMS value is computed as the square root of the average of the squares of the instantaneous amplitudes for one complete cycle.

Let's look at the effective (RMS) value of a sine wave which has a peak value of 100 V.

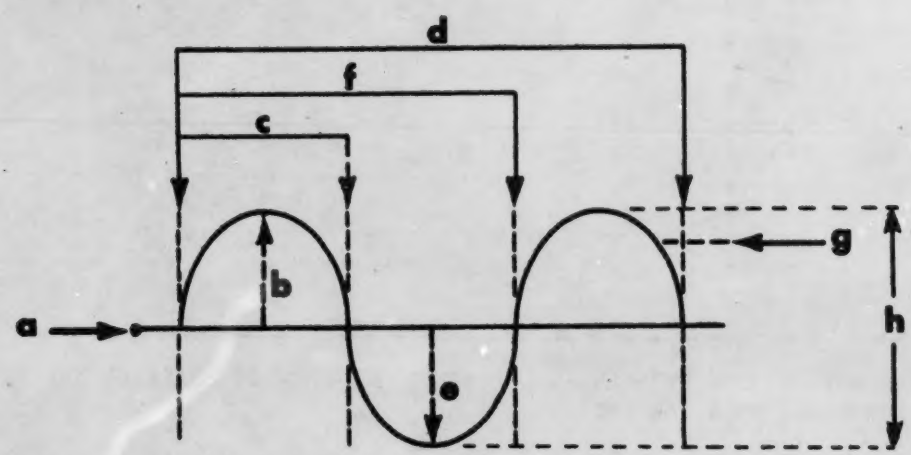


Select the lettered arrow which shows the effective value of voltage.



(b)

92. Match the lettered parts of the graph to their appropriate terms.



___ 1. sine wave

___ 2. cycle (Hertz)

___ 3. alternation

___ 4. negative peak amplitude

___ 5. positive peak amplitude

___ 6. zero EMF

___ 7. effective value (RMS)

___ 8. peak to peak amplitude

___ 9. period

- -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 92

1. d
2. f
3. c
4. e
5. b
6. a
7. g
8. h
9. f

IF ANY OF YOUR ANSWERS IS INCORRECT, GO BACK TO FRAME 64 AND TAKE THE PROGRAMMED SEQUENCE.

IF YOUR ANSWERS ARE CORRECT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, GO ON TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

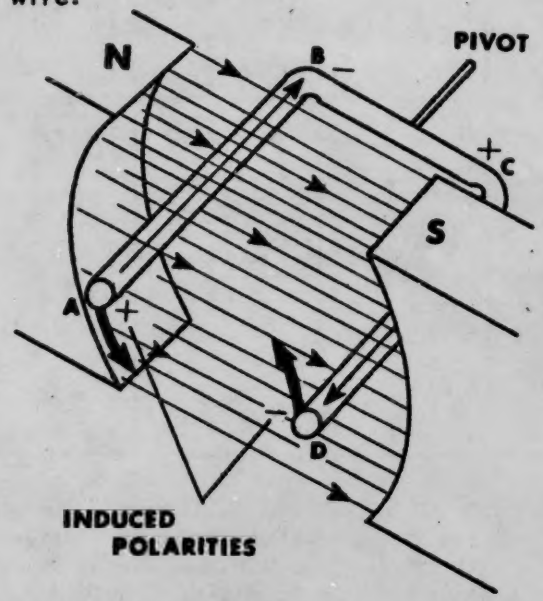
SUMMARY
LESSON IV

Generating AC Voltage

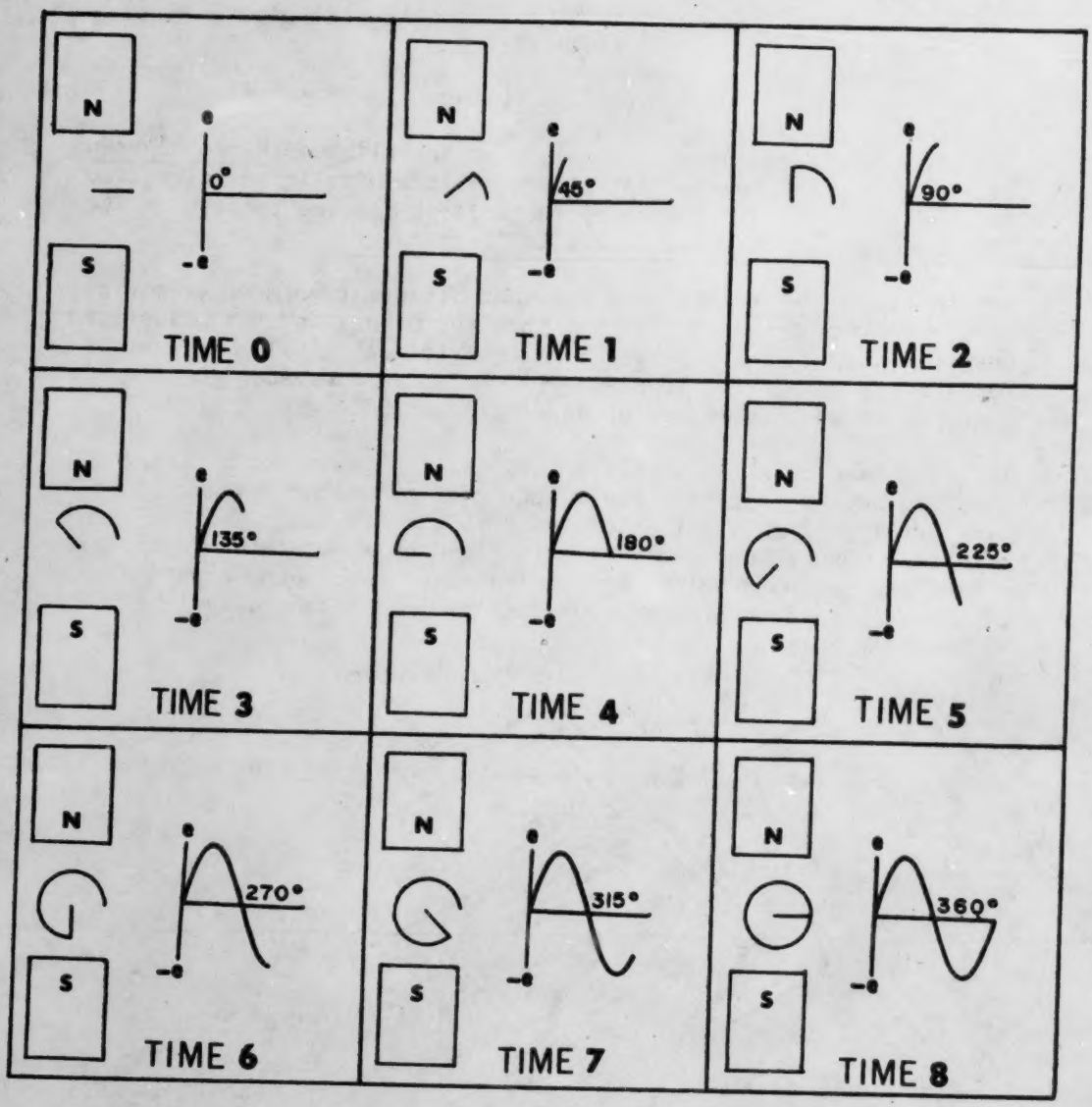
The electricity you have studied so far has all been direct current (DC). In DC, the movement of electrons is always in one direction through the circuit and usually the voltage remains constant. The EMF generated by batteries leads to DC-type current.

Alternating Current (AC) is a somewhat different form of electricity. AC moves first in one direction, then the other, and the associated EMF is always changing in value. Magnetic-mechanical generators, represented schematically as —(~)— , produce AC. You are now ready to study this method of developing an EMF.

The left-hand rule for generators is easily applied to a straight wire moving in a magnetic field, but most generators use coils of wire and the rule is a little more difficult to use. The two sides of a coil move through the magnetic field of a generator in opposite directions as shown below, but the voltages developed in each side of the coil tend to produce current flow in the same direction through the wire.



Imagine the number of magnetic lines of force being cut at various positions of the coil. As the coil rotates in the magnetic field, the output voltage will change in value and polarity as shown in the sketches on the following page. Because the waveform of the output varies as the sine of the angle of the loop's rotation, it is called a sine wave.



The EMF is zero when the wires of the coil move parallel to the lines of force, for no relative motion exists between them here (Time 0, Time 4, and Time 8). The output is maximum when the wires cut the greatest number of lines of force in a given instant; i.e., when their motion is perpendicular to the lines of force (Time 2 and Time 6).

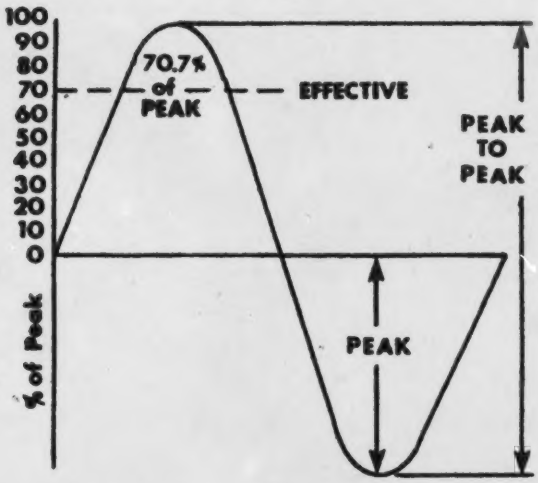
One complete set of voltage variations from zero to maximum positive to zero to maximum negative and back to zero is called a cycle. The frequency of any AC is the number of cycles per second generated. The basic unit of frequency is Hertz (Hz) and one Hz is equal to one cycle per second (cps).

The factors which determine the frequency of a generator are:

1. The speed of rotation of the armature (coil of wire).
2. The number of pairs of magnetic poles in the generator.

increasing either of these will increase the frequency of the generated AC.

Some other characteristics of a sine wave will be important to you in your study and work with electricity. Amplitude or the value of the waveform at any instant is one of these quantities. The value of a waveform at any instant of time is known as the instantaneous value of voltage or current and is symbolized by lower case letter for voltage (e) and current (i). The maximum or peak value of a sine wave (either positive or negative) is the greatest voltage (or current) present during a cycle, and the peak-to-peak voltage is the algebraic difference of the positive and negative peak values. You will probably use the effective (or RMS) value more often than any other, for it is directly comparable to DC values. Ten volts of DC and 10 volts of effective AC can do the same amount of work. Nearly all AC meters are calibrated in effective values, and any AC quantity which is stated without specifying the type of value is given in effective values.



This sketch of a sine wave may clarify the values for you.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK, OR YOU MAY STUDY THE LESSON NARRATIVE OR THE PROGRAMMED INSTRUCTION OR BOTH. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANOTHER METHOD OF INSTRUCTION UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM

M O D U L E T W O

L E S S O N V

Uses of AC and DC

Study Booklet

OVERVIEW

LESSON V

Uses of AC and DC

In this lesson you will study and learn about the following:

-AC generators
-uses of AC and DC

Each of the above topics will be discussed in the order listed. As you proceed through this lesson, observe and follow directions carefully.

BEFORE YOU START THIS LESSON, PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON V

Uses of AC and DC

To learn the material in this lesson, you have the option of choosing, according to your experience and your preferences, any or all the of the following:

STUDY BOOKLET:

Lesson Narrative
Programmed Instruction
Lesson Summary

ENRICHMENT MATERIAL:

NAVPERS 93400A-1a "Basic Electricity, Direct Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.: U. S. Government Printing Office, 1965.

NAVPERS 93400A-1b "Basic Electricity, Alternating Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.: U. S. Government Printing Office, 1965.

NAVPERS 10086-A "Basic Electricity." Chapter 8. Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.: U. S. Government Printing Office, 1965.

AUDIO-VISUAL:

Sound/Slide - "AC & DC Generators"

Remember, you may study all or any of these that you feel are necessary to answer all Progress Check questions correctly. Do not forget, that in one sense of the word, your instructor is a living resource, perhaps the best. Call him if you have any kind of a problem.

YOU MAY NOW STUDY ANY OR ALL OF THE RESOURCES LISTED ABOVE. YOU MAY TAKE THE PROGRESS CHECK AT ANY TIME.

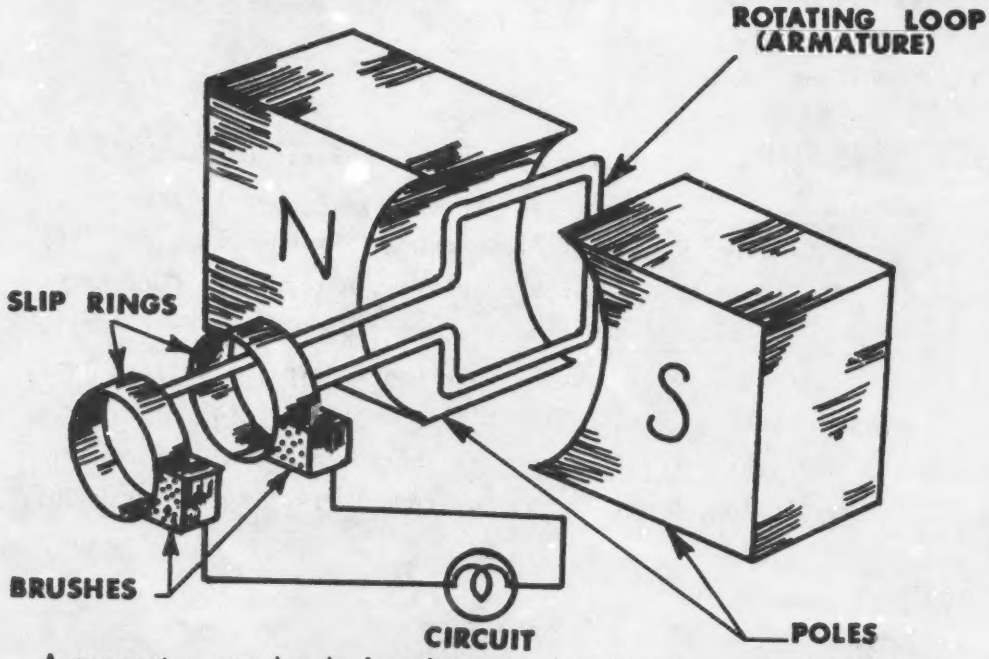
NARRATIVE
LESSON V

Uses of AC and DC

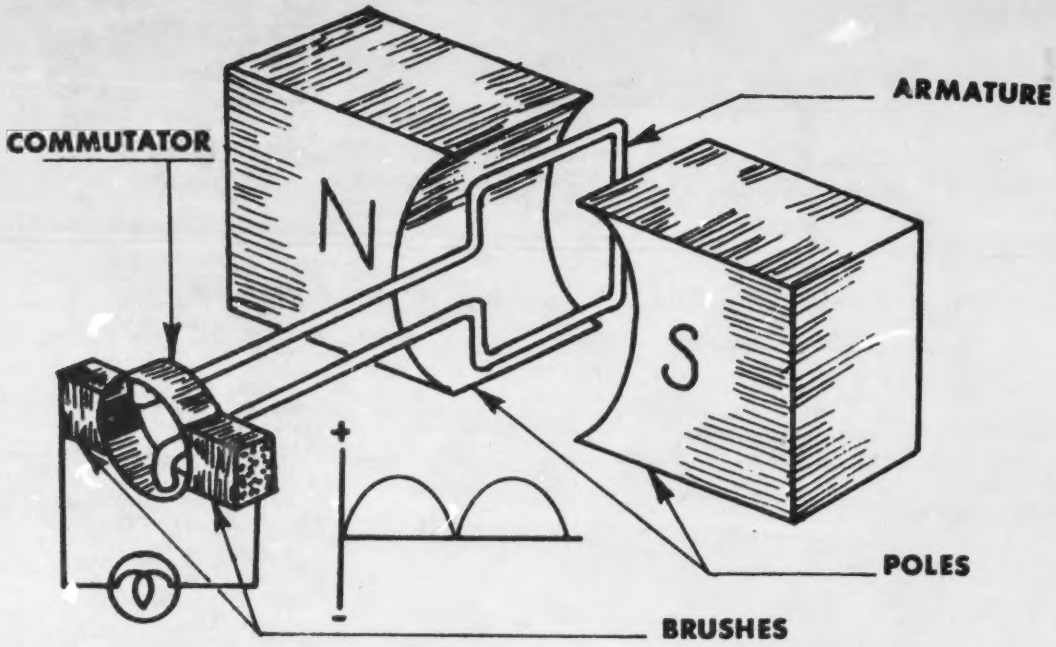
AC Generators

A machine that converts mechanical energy to electrical energy utilizing magnetism is called a generator, and generators that produce AC are often called by the special name alternators. The simplest form of an alternator is very much like the loop of wire you have seen rotating in a magnetic field. In fact, the only change needed to make it an alternator is a practical way to connect the EMF produced to a circuit.

These connections are usually made from the rotating part of the alternator (armature) to the stationary circuit. This is done without twisting and breaking the wires by use of slip rings and brushes. The slip rings are copper sleeves which rotate with the armature, and the brushes are carbon blocks held against the slip rings to make a good electrical connection. The diagram below shows the parts of an alternator.



A generator can be designed to provide direct current instead of alternating current. This is accomplished by using a commutator in place of the slip rings. The commutator reverses the armature connections to the external circuit each time the polarity of the EMF changes, and current then flows in the same direction in the external circuit all the time. A drawing of such a generator and a graph of its output appears on next page. The output graph shows that both alternations are in the positive direction because the commutator reverses the loop connections to the circuit at the time the generators output is zero.



Uses of AC and DC

You probably wonder now why you should have to learn about two different kinds of current flow. The answer is that both kinds are used very widely. You are probably most familiar with AC for it is commonly used to supply homes and ships. It is widely used because it can be transmitted over long distances more economically than DC and it is more efficient for driving motors,

DC is used when voltage fluctuations and direction changes cause trouble. Many circuits in radios, television sets, phonographs, and instruments which use amplifiers will not work properly on AC. You know that your house current is AC and your radio and TV operate when they are plugged into your house current. How can these things be true? The secret is that both the radio and TV have power supplies which convert the AC from the wall socket into DC for use inside the set.

You have finally found out <u>what</u> your power supply does; all we have to do now is find out <u>how</u> it does it.

AT THIS POINT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON V

Uses of AC and DC

TEST FRAMES ARE 10 AND 27. AS BEFORE, GO FIRST TO TEST FRAME 10 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. Recall from the previous lesson that AC is generated by a _____.

(generator or alternator)

2. The generator has two major parts: (1) a stator and (2) the armature.

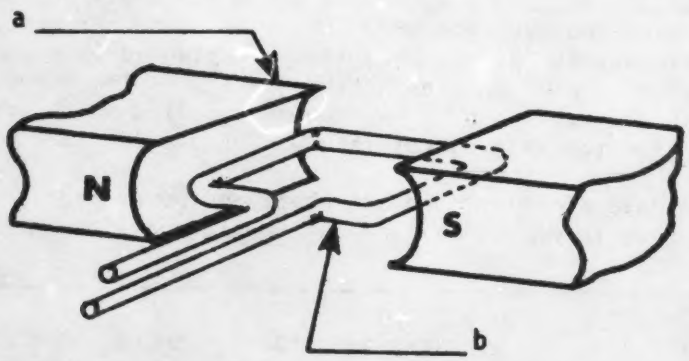
   The part of the generator which does not move is the:

   ___ a. armature.
   ___ b. stator.

(b) Stator

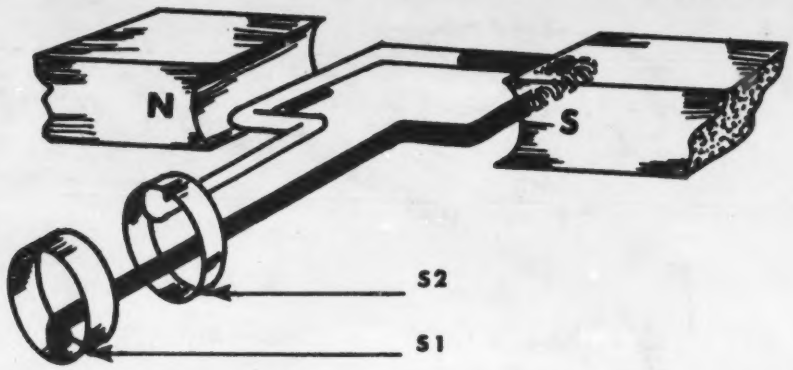
3. The armature in the generator consists of the rotating loop and its frame.

   Select the arrow showing the armature.



(b)

4. Let's continue and see what else makes up a generator. Some method must be available to make use of the induced EMF.



Here's an illustration of the basic AC generator again. Notice that the ends of the coil are connected to two metal rings. These rings rotate with the coil. They are called slip rings. S1 is the _____ _____ for the black side of the coil. Notice that the black side of the coil passes through S2 without touching it. S2 is the _____ _____ for the white side.

(slip ring; slip ring)

5. The slip rings are firmly attached to the free ends of the rotating loop to provide a contact point from which to pickup the voltage developed. The sliding contact is necessary to prevent the leads from tangling as the armature turns.

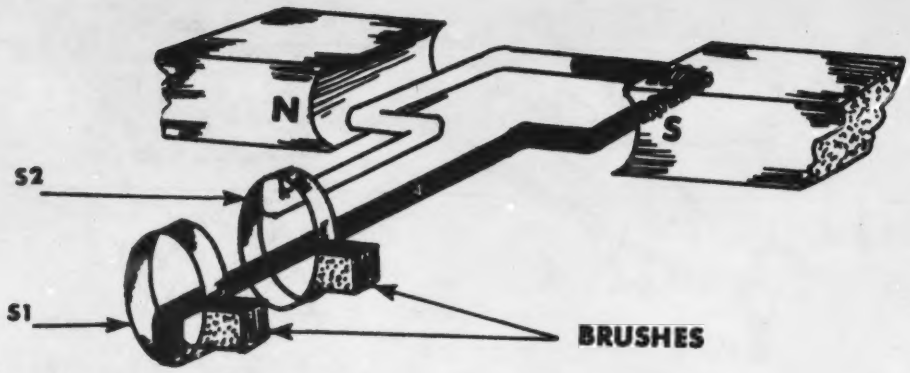
That portion of the alternator which provides a pick-up point for the voltage developed in the loop is the _____.

(slip ring)

6. Connected to the ends of the coil are two metal rings, called _____. When the coil rotates, the two metal rings _____ also.

(slip rings; rotate or move)

7.



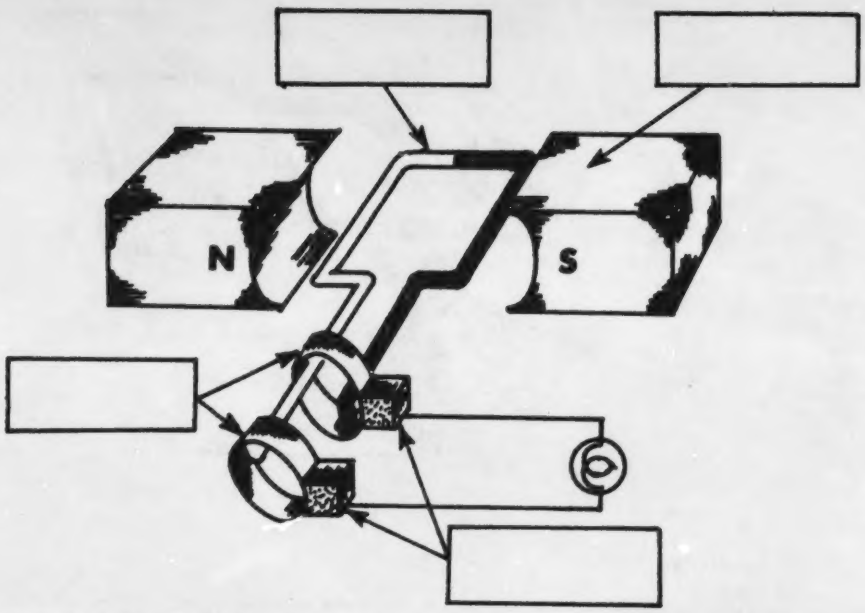
The figure shows two small blocks, called brushes, placed against the slip rings. The brushes are usually made of carbon or graphite. The purpose of the _____ and _____ is to connect the voltage generated in the _____ to an external circuit.

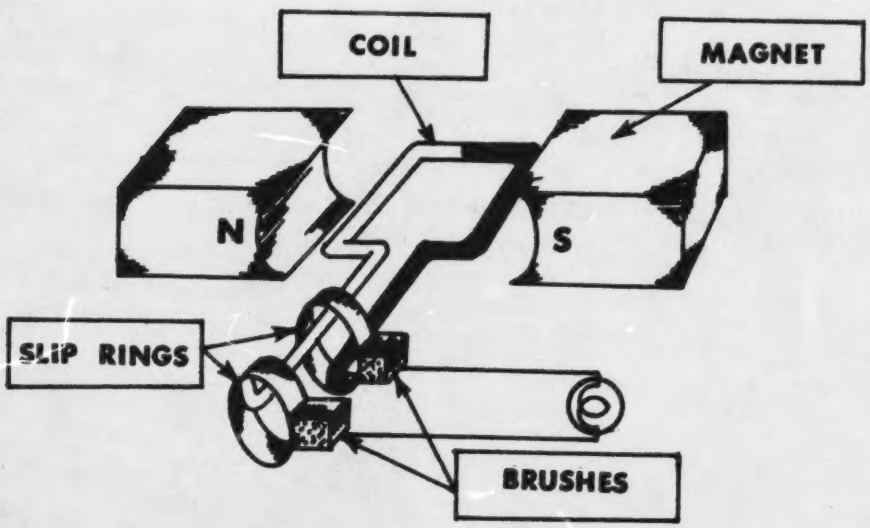
(slip rings; brushes; coil)

8. The brushes, which are normally made of carbon, press against the slip rings. They pick up the voltage from the slip ring and transfer it to a load in an external circuit. These brushes are stationary. They slide on the slip rings as the loop turns. The parts of the alternator which pick up the voltage and apply it to the load are called the _____.

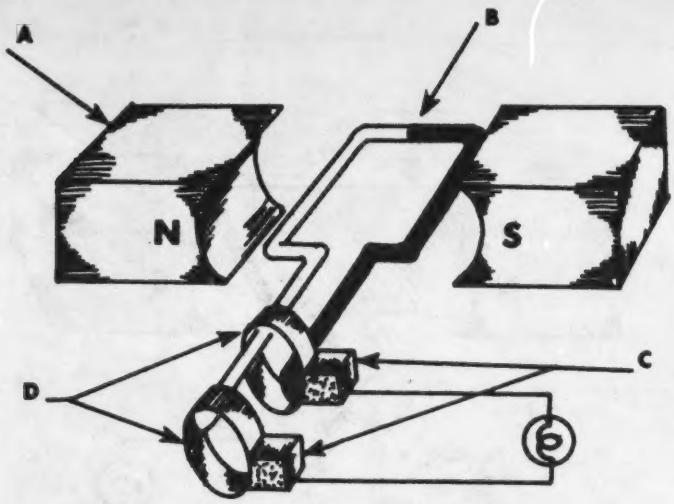
(brushes)

9. Here is the basic AC generator. Label the parts in the boxes provided.





10. Match the lettered parts in the diagram to their appropriate names or functions.



____ 1. armature

____ 2. slip rings

____ 3. brushes

____ 4. rotating loop

____ 5. creates lines-of-flux

____ 6. magnet

- -

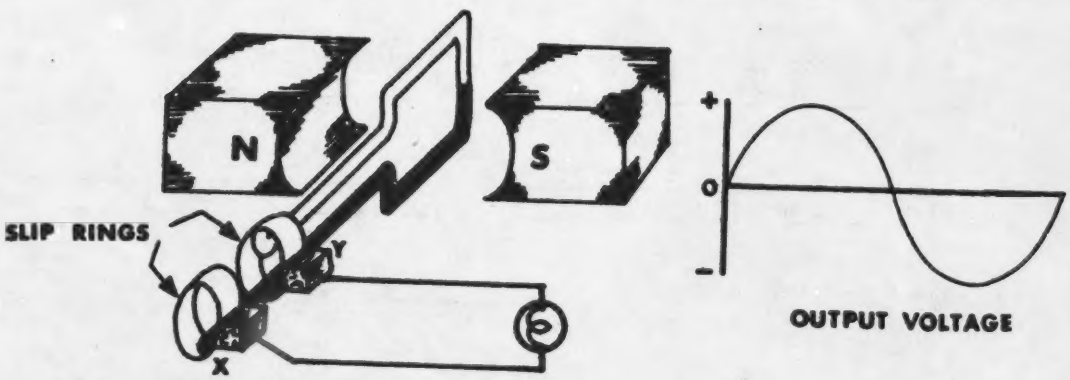
(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 10

1. b
2. d
3. c
4. b
5. a
6. a

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 27. IF NOT, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 10 AGAIN.

11. There are two methods of removing power from a generator, depending upon the type of generator (AC or DC). We have seen on the basic single-loop generator that, in order to make use of the EMF induced in the rotating coil, the two ends of the coil are connected to two _____ _____.



(slip rings)

12. Each ring is continuous, and is insulated from the shaft and from the other _____ _____.

(slip ring)

13. The two carbon brushes (X and Y in the figure, frame 11) which are connected to the load (lamp) rest on the _____.

(slip rings)

14. As the coil is rotated, the brushes make sliding contact with the _____ _____, completing the circuit at all times.

(slip rings)

15. Alternating current is described as current which periodically reverses direction. The EMF induced in a rotating coil is alternating, and through the use of slip rings, the output voltage is also _____.

(alternating)

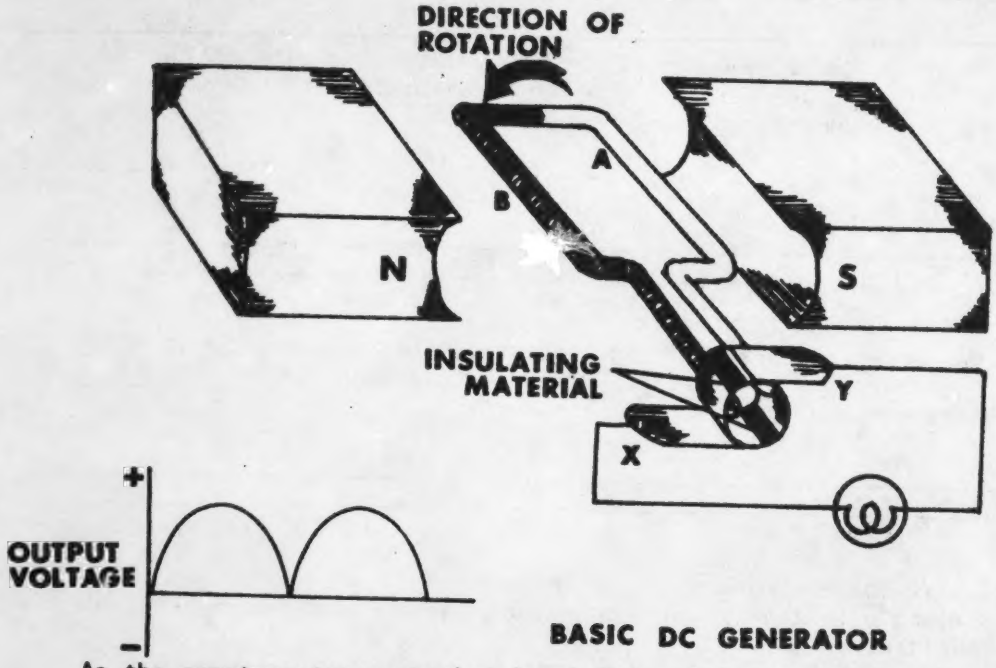
16. An AC voltage is taken from an AC generator by the use of _____ _____ and _____.

(slip rings and brushes)

17. Slip rings are used in _____ generators.

(AC)

18. Since the EMF induced in any rotating coil is alternating, slip rings cannot be used in a DC generator to conduct direct current from the coil to the external load. Instead, one split ring (or commutator) is substituted for the two slip rings. As shown in the figure below, each half of the split ring is temporarily making contact with one side of the generator coil. As shown brush X is positive with respect to brush Y.



BASIC DC GENERATOR

As the armature turns so that brush X is wiping the commutator section attached to the white side of the armature, what is the polarity of brush X to brush Y? _____

(positive)

19. As you can see, as the armature rotates, brush X shifts from one side of the armature to the other side. This shift causes the output voltage to be of constant _____, and the shift is accomplished by use of a _____.

(polarity; commutator)

20. A _____ is used to keep the outside circuit current flowing continually in the same direction in a DC generator.

(commutator)

21. Both AC and DC generators produce alternating current in their armature coils. By using a commutator, the output of a _____ (AC/DC) generator is a _____ (AC/DC) voltage.

(DC; DC)

22. As we found earlier in this program, another name for an AC generator is alternator. Slip rings are used in an _____.

(alternator)

23. List the two methods of collecting EMF from a generator, along with the type of generator in which each method is used. (either order)

_____ are used in _____ (AC/DC) generators.

_____ are used in _____ (AC/DC) generators.

(commutators - DC; slip rings - AC)

24. As you recall, direct current flows in one direction only. The type of current which reverses direction periodically is called alternating current.

Alternating current can be described as:

____ a. current which flows in one direction only.
____ b. current which flows in both directions at once.
____ c. current which periodically reverses direction.
____ d. current which never changes direction.

(c) current which periodically reverses direction

25. Why go to all the trouble of having AC and DC? AC is usually used to transmit energy over great distances because the losses are low. Low voltage DC transmission is more likely to be used for:

____ a. long distances.
____ b. short distances.

(b) short distances

26. AC voltages can also be increased or decreased in magnitude with very little loss. This is done in your power supply by the transformer.

State the purpose of your power supply transformer.

(To increase or decrease the voltage)

27. Write, as appropriate, AC or DC in the space provided.

____ a. Usually used for transmission over great distances with low loss of energy.

____ b. The output generated does not vary in direction and magnitude.

____ c. Generator has its contact ring divided into segments (commutator).

____ d. Generator has slip rings which transmit EMF to the load.

____ e. Voltage may be increased or decreased in value with a low loss of energy.

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 27

a. AC

b. DC

c. DC

d. AC

e. AC

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO FRAME 28. IF NOT, GO BACK TO FRAME 11 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 27 AGAIN.

---

28. The use of DC is limited, especially around the home. About the only place it is found is in a radio or television. But are not both the radio and television plugged into the AC outlets? They sure are! So how do they get DC power from an AC line? Very simple. Remember your power supply? Inside your radio and television are power supplies very similar to the one you built. They contain especially designed circuits that convert AC into DC. The DC is then supplied for the circuits requiring it.

Power supplies convert ____ to ____.

(AC to DC)

29. The primary purpose of the power supply is to:

____ a. step up voltage.
____ b. convert AC to DC.
____ c. step down current flow.

(b) convert AC to DC

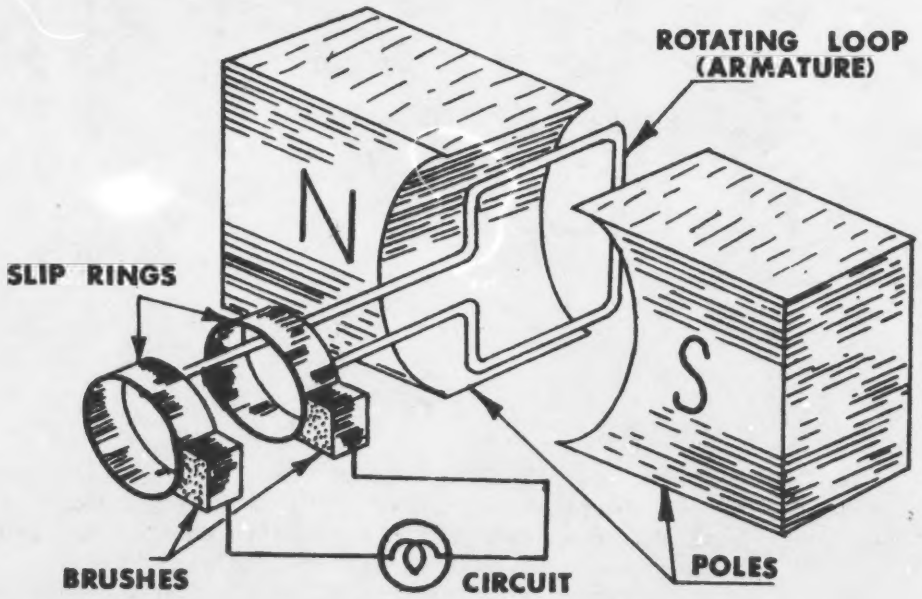
(NOTE: While it is true that voltages may be stepped up in a power supply, this is not the primary purpose.)

IF YOU FEEL YOU UNDERSTAND THIS MATERIAL, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, GO ON TO THE NEXT LESSON. IF NOT, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

SUMMARY
LESSON V

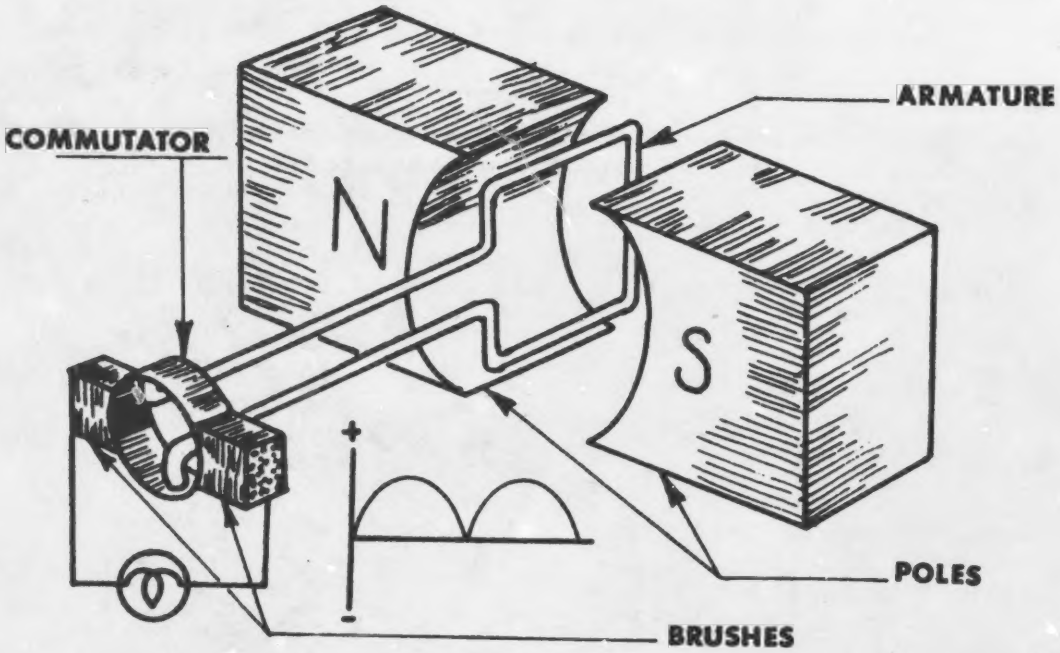
Uses of AC and DC

An AC generator is usually called an alternator, indicating that its output is alternating current. The simple machine which produced the sine wave in the last lesson needs only a method for connecting its output to a circuit without twisting and breaking the wires to be an alternator. This is done by the use of brushes and slip rings as shown here:



The brushes are made of a soft material, often carbon, and slide against the rotating slip rings to make the electrical connection from the alternator to the lamp. A variation of the slip rings can be used to change the generated AC to DC. This device (commutator) keeps one brush connected to the positive end of the loop at all times. A commutator and its output waveforms are shown below. Notice that the brushes are arranged so that the switch is made when the output of the loop is zero.

(See next page)



The reason we must deal with both AC and DC flow, is that each one has certain very useful characteristics. AC is more economical to transmit over long distances, and it is more efficient for driving motors. On the other hand, DC must be used in radios, TV sets, hi-fi's, etc., for the voltage changes of AC would ruin their sound or picture. A power supply is used in these sets which converts AC to DC. Now you know what your power supply does; all you have to learn is how it does it.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK, OR YOU MAY STUDY THE LESSON NARRATIVE OR THE PROGRAMMED INSTRUCTION OR BOTH. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL OF THE QUESTIONS CORRECTLY, GO TO THE NEXT LESSON. IF NOT, STUDY ANOTHER METHOD OF INSTRUCTION UNTIL YOU CAN ANSWER ALL THE QUESTIONS CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS
INDIVIDUALIZED LEARNING SYSTEM

M O D U L E T W O

L E S S O N V I

Measuring Voltage

Study Booklet

OVERVIEW
LESSON VI

Measuring Voltage

In this lesson you will study and learn about the following:

- -where voltage can be measured
- -the voltmeter
- -measuring voltage in a circuit
- -measuring voltage of cells in series
- -measuring voltage of cells in parallel
- -measuring cells connected in series opposition
- -measuring cells connected in series and in series opposition

Each of the above topics will be discussed in the order listed. As you proceed through this lesson, observe and follow directions carefully.

BEFORE YOU START THIS LESSON, PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES

LESSON VI

Measuring Voltage

To learn the material in this lesson, you have the option of choosing, according to your experience and your preferences, any or all of the following:

STUDY BOOKLET:

Lesson Narrative

Programmed Instruction

Lesson Summary

ENRICHMENT MATERIAL:

NAVPERS 93400A-1a "Basic Electricity, Direct Current." Fundamentals of Electronics. Bureau of Naval Personnel. Washington, D.C.: U.S. Government Printing Office, 1965.

AUDIO-VISUAL:

Sound/Slide - "The Voltmeter"

YOU MAY NOW STUDY ANY OR ALL OF THE RESOURCES LISTED ABOVE. YOU MAY TAKE THE PROGRESS CHECK AT ANY TIME. UPON COMPLETION OF THIS LESSON YOU SHOULD ASK YOUR INSTRUCTOR FOR THE MODULE TEST COVERING ALL THE LESSONS IN THIS BOOKLET. YOU MAY REVIEW PREVIOUS LESSONS IF YOU WISH.

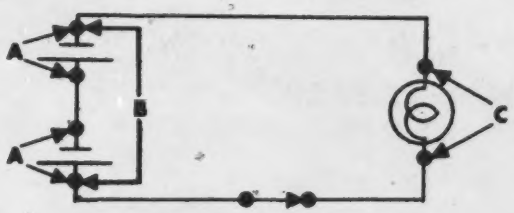
NARRATIVE
LESSON VI

Measuring Voltage

Where Voltage Can Be Measured

You learned earlier that voltage is measured in units called volts, and that the alphabetic symbol for volt is V. Another term you have come across is difference of potential. Voltage can be measured only between points that have a difference of potential; one way for this to occur is to have a difference in the electrical charge associated with the two points. This potential difference can exist in parts of a circuit where there is an EMF generated (voltage rise) or where voltage is being used (voltage drop).

Energy (the ability to do work) is added to a circuit at the circuit's source, that is, battery, dry cell, or generator. Energy is put to work in the circuit by the load - light bulb, toaster, radio, etc. Load is a general term for anything using energy in an electrical circuit. In a circuit using two dry cells and a lamp, voltage differences can be measured between (A), the terminals of either cell, (B), across both cells, or (C), across the load.



Voltage usually cannot be measured across a closed switch or between two points connected by a wire because there is almost no difference in the potential between these points.

Electrical energy is usually neither added nor used between such points.

The Voltmeter

The device used to measure voltage is called a voltmeter. Remember that the schematic symbol for an ammeter was a circle with an A in it (—(A)—). The voltmeter's schematic symbol is almost the same thing. It is a circle with the letter V inside (—(V)—).

The ammeter was connected in series with a circuit component so that it could measure the current through that component.

Because the voltmeter measures the difference in potential between two points, it is connected between those points, and the circuit is not opened to make this connection. We say that the voltmeter is connected in parallel with the component across which we want to measure voltage. The diagram below shows a voltmeter connected across a light bulb to determine the voltage dropped by the light bulb.

Polarity must be observed in DC circuits; voltmeter probes must be inserted in the voltmeter jacks with red probe in red jack and black probe in black jack.

When you measure voltage there are several steps in making the reading. The method given here is to be used when measuring low voltages (30 v or less) only.

1. Hold the probes by the insulated plastic handles only. Gripping any other part of the probe or wire may make you part of the circuit - not a comfortable or safe situation.
2. Always be certain the meter can measure the voltage in the circuit. If the voltage is too high for the meter, it will damage, possibly destroy, the meter.
3. DC voltmeters are polarity sensitive just like DC ammeters. Connecting one in reverse may bend its pointer or jam the meter. Always connect the negative (black or -) probe to the point nearest the negative side of the source and the positive (red or +) probe to the point nearest the positive terminal of the source.
4. Read the voltage on the face of the meter.
5. Remove probes from the circuit.

Earlier in the module you learned that if cells are connected in different ways, different voltages will result. Now you can prove this to yourself by taking actual measurements.

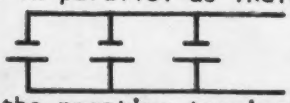
Measuring Voltage of Cells in Series

1. Get a voltmeter from the resources center.
2. Connect three 1-1/2-volt cells in series.
3. Touch the positive meter probe to the positive terminal of the cell which has no wire connected to it.
4. Touch the negative meter probe to the negative terminal of the cell which has no wire connected to it.
5. What does the voltmeter indicate? _____

You should get an indication of approximately 4-1/2 volts, proving that voltages of cells connected in series are additive.

Measuring Voltage of Cells in Parallel

1. Connect three 1-1/2-volt cells in parallel as indicated by the schematic representation.

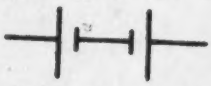


2. Touch negative meter probe to the negative terminal of any cell.
3. Touch positive meter probe to the positive terminal of any cell.
4. What is the meter indication? _____

The meter indicates approximately 1-1/2 volts proving that cells connected in parallel have the same output voltage as one cell.

Measuring Voltage of Cells Connected in Series Opposition

1. Connect two 1-1/2-volt cells in series opposition as the schematic representation indicates.

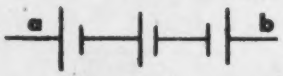


2. Touch negative probe of meter to the positive terminal of either cell.
3. Touch positive probe of meter to the positive terminal of the other cell.
4. What is the meter indication? _____

The meter indicates 0 volts, proving that when cells are connected in series opposition, the voltages are subtractive.

Measuring Voltage of Cells Connected in Series Aiding and in Series Opposing

1. Connect two 1-1/2-volt cells in series aiding and a third 1-1/2-volt cell in series opposition to the first two.



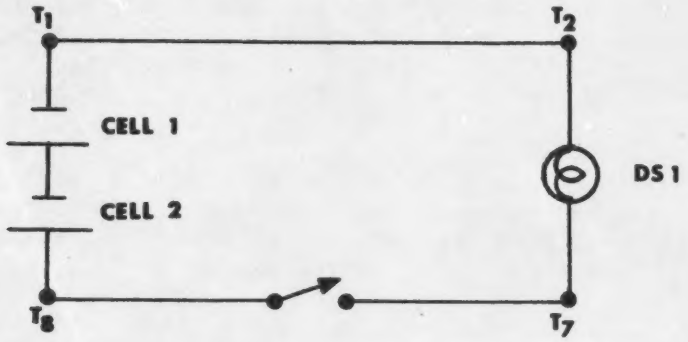
2. Touch negative meter probe to terminal b.
3. Touch positive meter probe to terminal a.
4. What does the voltmeter indicate? _____

The meter indication is 1-1/2 volts. This is explainable because you connected two cells in series providing 3 volts between them. Then by connecting another cell in series opposition, you have cancelled 1-1/2 volts of the 3 volts.

Now let's take measurements in a circuit.

Measuring Voltages in a Circuit

Using PB 0-1, two dry cells, and connecting wires, set up a circuit as show by the schematic diagram.



Using your voltmeter and test leads, measure voltage in the circuit as follows:

1. Connect red positive probe to T8. (Touch only red plastic sleeve of the probe.)
2. Connect black negative probe to T1.
3. a. Record voltage between T8 - T1. _____
   b. Measure and record voltage between T8 - T2. _____
   c. Measure the difference in potential between T8 and the negative terminal of cell 2. _____
   d. What is the voltage between the negative terminal of cell 2 and T1? _____
   e. Close switch.
      Read and record voltage between T2 - T7. _____.
      Is it a voltage rise or a voltage drop? _____
   f. With switch closed, what is the difference in potential between T7 - T8? _____
   g. Are the cells in this circuit connected in series or parallel? _____

Check your answers with those on the next page.

Answers:

Recall that meter readings are approximate because tolerances must be considered.

3. a. 3 v
   b. 3 v
   c. 1-1/2 v
   d. 1-1/2 v
   e. 3 v drop
   f. 0
   g. series

NOW YOU MAY EITHER TAKE THE PROGRESS CHECK OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, YOU HAVE MASTERED THE MATERIAL AND ARE READY TO TAKE THE MODULE TEST. SEE YOUR INSTRUCTOR.

IF YOU DECIDE NOT TO TAKE THE PROGRESS CHECK AT THIS TIME, OR IF YOU MISSED ONE OR MORE QUESTIONS, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU HAVE ANSWERED ALL THE PROGRESS CHECK QUESTIONS CORRECTLY. THEN SEE YOUR INSTRUCTOR AND ASK TO TAKE THE MODULE TEST.

PROGRAMMED INSTRUCTION
LESSON VI

Measuring Voltage

TEST FRAMES ARE 5, 13, 15, AND 18. AS BEFORE, GO FIRST TO TEST FRAME 5 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. Recall that the units of potential difference are _____.

(volts)

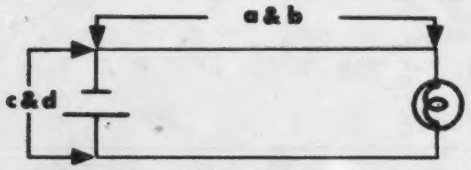
2. The alphabetical symbol for a volt is:

___ a. a
___ b. Ω
___ c. v
___ d. E

(c) v

3. To measure voltage, a difference of potential must exist.

Which letters indicate where a difference of potential exists?

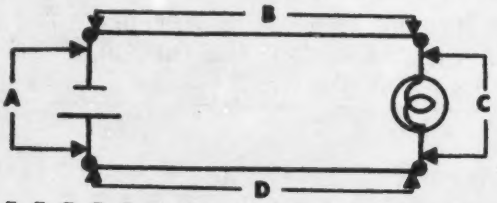


(c & d)

4. In a complete electrical circuit, a difference of potential can occur only:

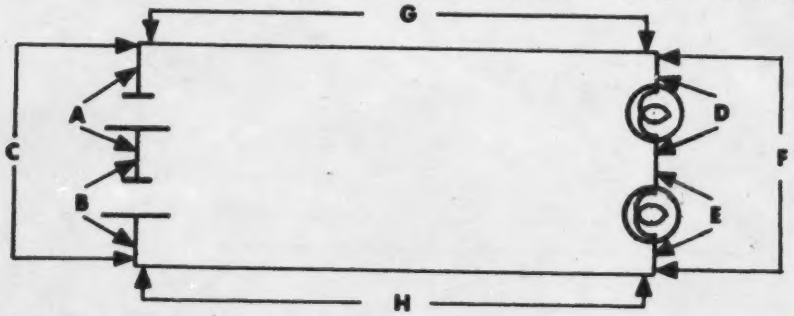
   1. at the terminals of a source.
   2. at the terminals of a load.

   Circle the letters that indicate where a difference of potential can occur.



(a and c)

5. Indicate the point or points where a potential difference exists.



(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 5

a, b, c, d, e, and f

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 13. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 5 AGAIN.

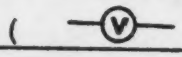
6. Which of the following meters would be used to measure voltage?

___ a. ammeter
___ b. voltmeter
___ c. ohmmeter

(b) voltmeter

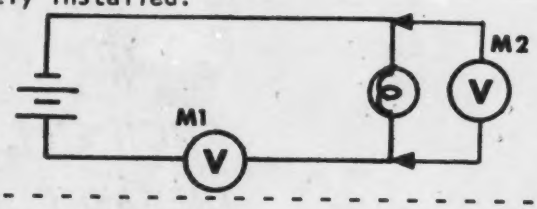
7. The symbol for the voltmeter is a circle with a v inside it.

Draw the symbol for a voltmeter.

()

8. A voltmeter, unlike the ammeter, must be hooked across (in parallel to) the difference in potential to measure voltage.

Which voltmeter is correctly installed.

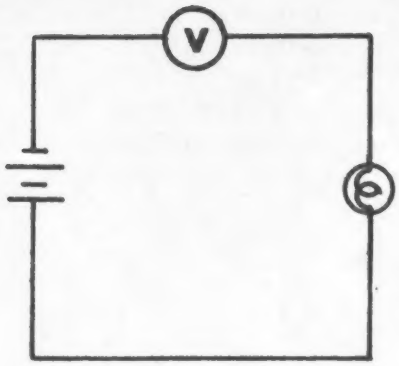


(M2)

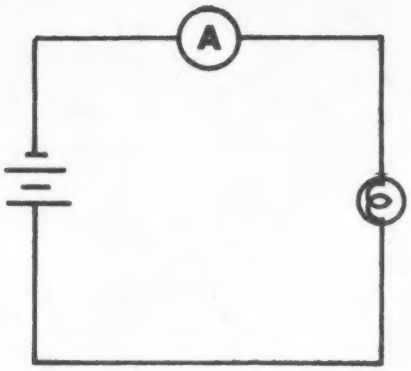
9. Draw a schematic diagram for a simple circuit (cell, conductor, lamp, and switch) with a voltmeter measuring source voltage.

10. Check the schematics that show the meter correctly installed.

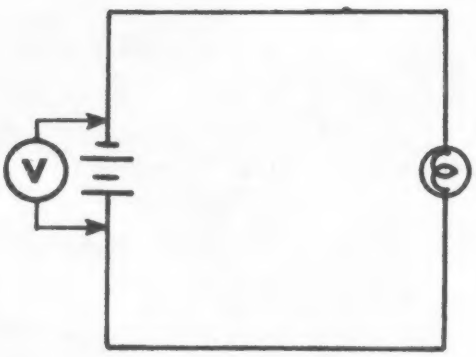
___ A



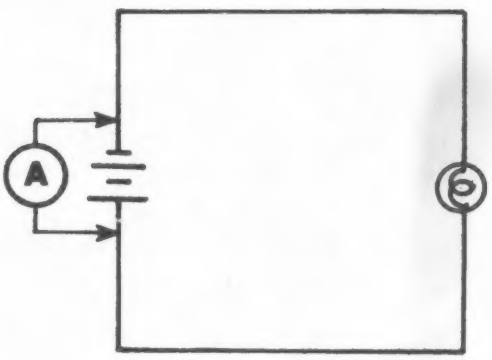
___ C



___ B



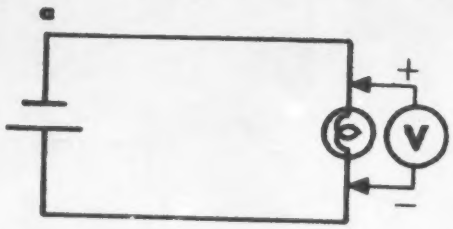
___ D



(B and C)

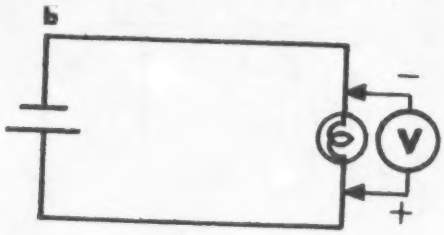
11. The voltmeter like the ammeter is polarity sensitive.

a



Which schematic shows the voltmeter installed correctly?

b



- - - -

13. Write the steps and precautions used to measure voltage.

1. _____

2. _____

3. _____

4. _____

5. _____

- -

_____

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 13

1. Hold probes by insulated plastic handles only.
2. Ensure meter has the range to measure the voltage expected in the circuit.
3. Ensure correct polarity.
4. Read voltage from meter.
5. Remove probes from circuit.

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 15. OTHERWISE, GO BACK TO FRAME 6 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 13 AGAIN.

If you have not done the Narrative, turn to page 152 of this lesson and perform the measurements in the following:

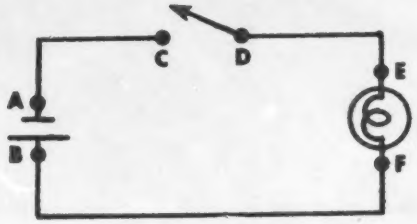
-Measuring Voltage of Cells in Series - Page 153
-Measuring Voltage of Cells in Parallel - Page 154
-Measuring Voltage of Cells Connected in Series Opposition - Page 154
-Measuring Voltage of Cells Connected in Series Aiding and in Series Opposition - Page 154
-Measuring Voltages in a Circuit - Page 155

After you have performed these measurements, go to frame 14.

14. Take the power supply you built in Module Zero and a voltmeter. Measure and record the voltage between the switch and T6 (across the lamp). _____

(5 to 8 volts)

15. Build a simple circuit according to the schematic below.



Measure and record the following voltages:

___ a. at the source.
___ b. across the load.
___ c. across open switch.
___ d. across straight wire between points B and F

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWERS - TEST FRAME 15

a. 1.5v
b. 0v
c. 1.5v
d. 0v

- -

IF ALL YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 18. OTHERWISE GO BACK TO FRAME 14 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 15 AGAIN.

16. In frame 15, you read 0 volts between points B and F because there was:

___ a. a difference of potential.
___ b. a voltage drop.
___ c. no difference in potential.
___ d. a voltage rise.

- -

(c) no difference in potential

17. Since there was no current flow and therefore no voltage drop in the circuit, source voltage was present across the open switch.

With no current flow there can be:

___ a. no voltage rise.
___ b. no voltage drop.
___ c. no difference in potential across the load.
___ d. a difference in potential across the load.

- -

(b. no voltage drop; and c. no difference in potential across the load)

18. Check the statement that is correct.

___ a. Voltage registers across a closed switch because of a voltage drop.
___ b. Voltage registers across a closed switch because of a rise in potential.
___ c. Voltage registers across a load because of a voltage drop.

- -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

ANSWER - TEST FRAME 18

c. Voltage registers across a load because of a voltage drop.

- -

IF YOUR ANSWER IS INCORRECT, GO BACK TO FRAME 16 AND TAKE THE PROGRAMMED SEQUENCE.

IF YOUR ANSWER IS CORRECT, YOU MAY TAKE THE PROGRESS CHECK, OR YOU MAY STUDY ANY OF THE OTHER RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, YOU HAVE MASTERED THE MATERIAL AND ARE READY TO TAKE THE MODULE TEST. SEE YOUR INSTRUCTOR.

IF YOU DECIDE NOT TO TAKE THE PROGRESS CHECK AT THIS TIME, OR IF YOU MISSED ONE OR MORE QUESTIONS, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU HAVE ANSWERED ALL THE PROGRESS CHECK QUESTIONS CORRECTLY. THEN SEE YOUR INSTRUCTOR AND ASK TO TAKE THE MODULE TEST.

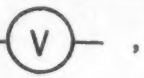
In this frame sequence you learned (1) the steps for voltage measurement and (2) how to use a simple voltmeter.

SUMMARY
LESSON VI

Measuring Voltage

Voltage can be measured only across points between which there is a difference of potential; the usual way for this to happen is for the two points to have different amounts of electrical charge associated with them. This condition exists in parts of a circuit where there is an EMF generated (voltage rise) or energy loss (voltage drop).

Energy is put into a circuit at its source and used by the load, for example, the light bulb, toaster, radio, etc. Voltage can be measured between the ends of a source or a load, but it usually cannot be measured between the ends of a piece of wire connecting these parts because usually there is almost no voltage rise or drop through a conductor.

The device used to measure voltage is called a voltmeter. Its schematic symbol is 

, and it is always connected between two points when you want to know their potential difference. Unlike current measurement, the circuit does not have to be broken to measure voltage. The steps in using a voltmeter for low (30v or less) voltages are:

1. Hold the probes by the insulated portions only.
2. Be certain the voltage is not higher than the meter can measure.
3. Observe polarity when measuring DC voltages.
4. Read the voltage and remove the probes from the circuit.

If you feel you need more information about measuring voltage, continue studying lesson VI; if not, perform the experiment Measuring Voltages at the end of the Narrative for this lesson.

NOW YOU MAY TAKE THE PROGRESS CHECK OR STUDY ANY OTHER OF THE RESOURCES LISTED. IF YOU TAKE THE PROGRESS CHECK AND ANSWER ALL THE QUESTIONS CORRECTLY, YOU HAVE MASTERED THE MATERIAL AND ARE READY TO TAKE THE MODULE TEST. SEE YOUR INSTRUCTOR.

IF YOU DECIDE NOT TO TAKE THE PROGRESS CHECK AT THIS TIME, OR IF YOU MISSED ONE OR MORE QUESTIONS, STUDY ANY METHOD OF INSTRUCTION YOU WISH UNTIL YOU HAVE ANSWERED ALL THE PROGRESS CHECK QUESTIONS CORRECTLY. THEN SEE YOUR INSTRUCTOR AND ASK TO TAKE THE MODULE TEST.